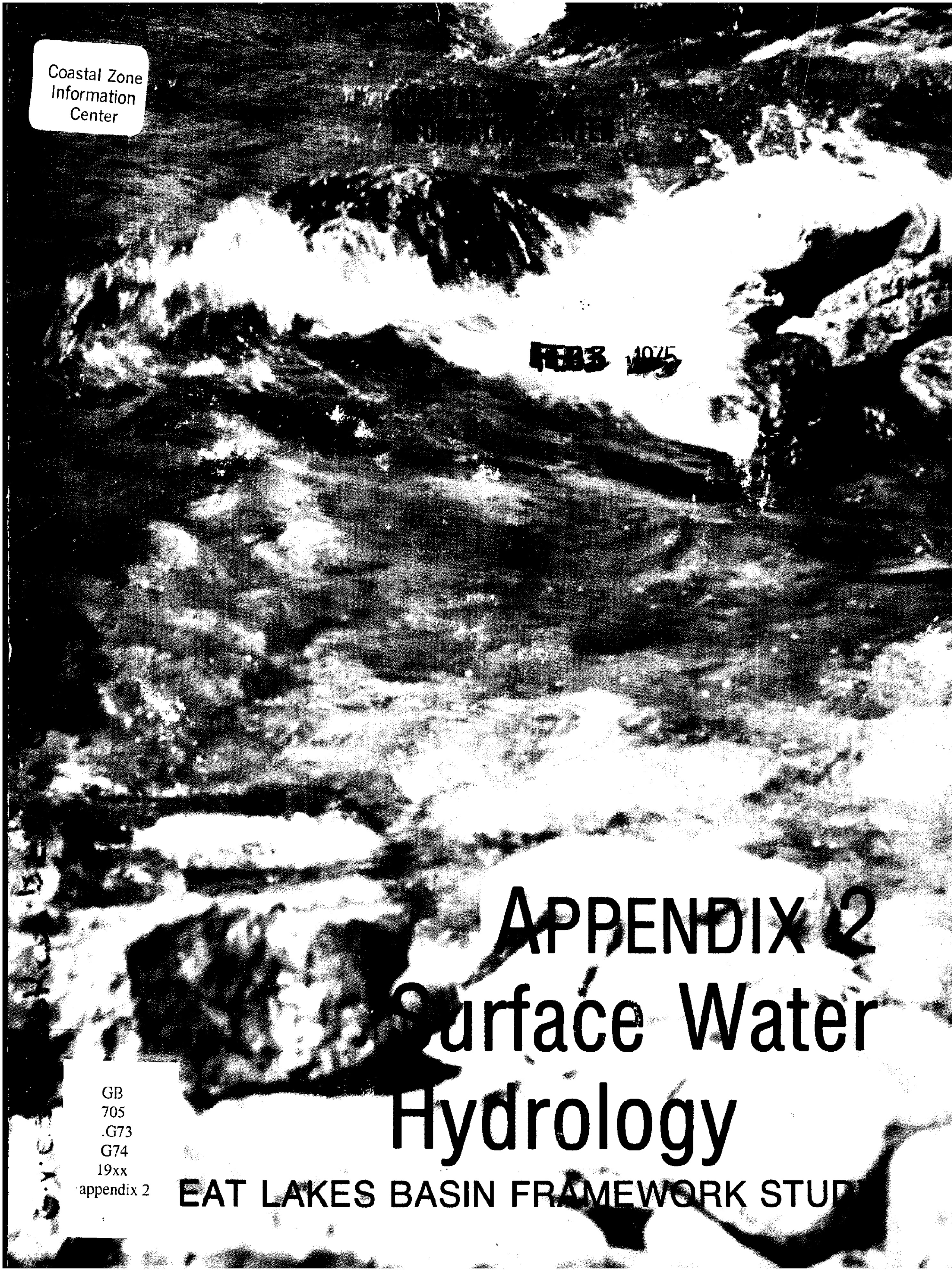

APPENDIX 2
Surface Water Hydrology

EAT LAKES BASIN FRAMEWORK STUD

Great Lakes Basin Framework Study

APPENDIX 2

SURFACE WATER HYDROLOGY

GREAT LAKES BASIN COMMISSION

Prepared by Surface Water Hydrology Work Group

Sponsored by U.S. Department of the Army

Corps of Engineers

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This appendix to the *Report* of the *Great Lakes Basin Framework Study* was prepared at field level under the auspices of the Great Lakes Basin Commission to provide data for use in the conduct of the Study and preparation of the *Report*. The conclusions and recommendations herein are those of the group preparing the appendix and not necessarily those of the Basin Commission. The recommendations of the Great Lakes Basin Commission are included in the *Report*.

OUTLINE

SYNOPSIS

Nearly all surface-water runoff from tributary streams in the Great Lakes Basin is supplied from precipitation falling within its boundaries. The influence of the Great Lakes together with bordering highlands is responsible for variations in areal and seasonal distribution of precipitation over the Basin. The rather wide variation in runoff among the planning subareas is primarily due to differences in geology, surficial features, climate, and land use rather than to difference in annual precipitation.

Flooding by rivers in the Basin is most common in late winter or early spring. Flooding is most often caused by high-intensity rainstorms or by a combination of snowmelt and rainfall on partially frozen ground. Flood stages are frequently increased by ice jams, especially at the mouth of a river where its capacity can be restricted by either sheet ice or windblown ice from the Lake.

Low flows occur each year on streams throughout the Basin, as runoff diminishes due to increased losses by evapotranspiration and seasonal variances in rainfall distributions. After surface runoff ceases, the entire flow of the stream is drawn from ground-water storage. As this storage is depleted, streamflow diminishes until either the stream goes dry or the supply is replenished by precipitation.

River forecasting is used to predict the amount of water that will find its way into rivers and streams and the time it will take to reach them under different conditions of temperature, soil moisture, and precipitation. Although river forecasting is usually associated with flood warning procedures, it can be of equal value when dealing with other water management problems such as drought flows.

An evaluation of the total surface water availability of a river basin is fundamental to sound water resource planning. The limits to which a stream can supply or yield water must be known before that fixed minimum amount can be allocated to sometimes conflicting demands upon the water. In order to satisfy future water needs, it may be necessary in some cases to stabilize streamflows through reservoir control.

Because of the unique hydrologic aspects of the Great Lakes Basin, additional studies are required of peak flows, low flows, and snowmelt runoff. An expanded stream forecasting program is also recommended to provide service to the remaining areas that have flood hazards.

FOREWORD

The material used in this appendix was furnished by the Geological Survey, U.S. Department of the Interior; Soil Conservation Service, U.S. Department of Agriculture; Department of the Army, Corps of Engineers, Buffalo District, Chicago District, Detroit District, and St. Paul District; the States of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, and Wisconsin; and the Commonwealth of Pennsylvania. This appendix was prepared by the Surface Water Hydrology Work Group.

The Surface Water Hydrology Work Group and its chairman from the St. Paul District, U.S. Army Corps of Engineers, consolidated data furnished by other work group members, coordinated work, prepared the appendix narrative, and published the draft appendix. The U.S. Geological Survey, through its district offices located within the Great Lakes Basin, its member on the work group, and its published reports, statistical summaries, and water supply papers, furnished most of the basic surface water runoff data included in the report. Coordination of data-gathering and analysis in the various planning subareas was the responsibility of work group members from the U.S. Army Corps of Engineers, St. Paul District, for Planning Subareas 1.1 and 1.2; Chicago District, for Planning Subareas 2.1 and 2.2; Detroit District, for Planning Subareas 2.3, 2.4, 3.1, 3.2, 4.1, and parts of 4.2; and Buffalo District, for Planning Subareas 4.3, 4.4, 5.1, 5.2, 5.3, and parts of 4.2. Work group members from the States of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Wisconsin, the Commonwealth of Pennsylvania, and the U.S. Soil Conservation Service furnished information on reservoir sites, agencies gathering data, bibliographic information, and published hydrological reports. All work group members also furnished suggested recommendations, guidance, and constructive comments during review of the draft appendix. The National Weather Service of the National Oceanic and Atmospheric Administration and the various State work group members furnished information on forecasting.

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INTRODUCTION

Objective and Scope

The overall objective of this appendix is to provide a generalized evaluation of surface water runoff entering the five Great Lakes and the St. Lawrence River from tributary streams in the United States. Of the 296,000 square miles in the entire Great Lakes Basin above the Lake Ontario outlet, approximately 113,000 square miles of contributory land area are in the U.S., and nearly 88,000 square miles are in Canada. An additional 4,800 square miles contribute to the St. Lawrence River in the U.S. below the Lake Ontario outlet. An analysis of runoff potentials from streams in Canada has not been made as part of this appendix. The appendix has been developed to the detail and scope required to determine only basic information needed to formulate a comprehensive framework plan for management of water and related land resources of the Great Lakes Basin within the United States.

Method of Analysis

Hydrologic determinations formulated in this appendix were based on current information already available for the Great Lakes Basin. No new basic data were gathered for the appendix. The appendix summarizes the programs of agencies involved in collecting data; the existing data collection program; quantitative information on the magnitude, distribution, and variability of surface runoff; water availability; reservoir sites; and runoff forecasting.

Methods of analysis used in this appendix for the evaluation of surface water runoff included standard hydrological tools of consolidation, compilation and summary of field-gathered runoff records, statistical discharge-frequency computations, and runoff mass curve analysis. In the absence of available data to cover streamflow conditions in every potential resource reach in the Basin, and in view of the cost and time required to develop these data, a methodology was developed that simulates conditions in ungaged areas based on data obtained in similar hydrologic areas. Thus, the method of analysis provides the framework study planner with a simplified but realistic tool for generating hydrologic data representative of conditions for areas generally void of streamflow records. For purposes of analysis, this appendix uses the boundaries of the planning subareas shown on Figures 2–1 through 2–15 to develop generalized data to be representative of all conditions within that planning subarea.

Historical Background

Various agencies on both the State level and Federal level have been gathering and compiling surface water hydrology records in the Basin since the early 1800s in the eastern end and early 1900s on the western tributaries to the Basin. As industry moved into the Basin to develop the mineral, forest, and water resources, additional hydrologic data were compiled. With the urbanization and industrialization of the Basin, the hydrologic regimen has been modified from its natural state, more so in the eastern regions of the Basin than in the northern and western regions. The evaluation of surface water hydrology has made no attempt to define the modification of the regimen through the years or to anticipate the changes which may occur in the future, but only to present the data currently available.

Study Relationship

The endless cycle of water movement from the atmosphere to the earth and back to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration is called the hydrologic cycle. This appendix evaluates only the surface water runoff phase of the cycle and, as such, is a basic data appendix. An evaluation of the complete water resource system includes evaluation of the other phases of the cycle which are included in Appendixes 3, 4, 11, 12, 14, 16, and 18. This appendix represents a consolidation and summary of data, prepared by the Surface Water Hydrology Work Group, and furnished to other work groups as working papers. The detailed working papers are available at the office of the Great Lakes Basin Commission.

Section 1

HYDROLOGIC DATA COLLECTION PROGRAM

1.1 Agencies Gathering Hydrologic Data

Within the United States portions of the Great Lakes Basin, the U.S. Geological Survey is the prime agency responsible for gathering, recording, and publishing of data on surface water hydrology. The most complete source of published data is the Water Supply Papers of the U.S. Geological Survey. The data are collected and prepared for publication in cooperation with other Federal, State, local, and private agencies. To a more limited extent and for specific purposes, many other Federal, State, county, and municipal agencies plus public and private corporations and individuals gather and record surface water data not published in the Water Supply Papers. Federal agencies, in addition to the U.S. Geological Survey, that gather stage and discharge data within the Basin include the National Weather Service, U.S. Army Corps of Engineers, Agricultural Research Service, U.S. Department of Health, Education and Welfare, Environmental Protection Agency, U.S. Bureau of Mines, and U.S. Forest Service. State agencies that gather surface water data include the State conservation departments, departments of natural resources, health departments, pollution control agencies, State geological surveys, highway departments, State water surveys, and other water-oriented agencies. On the county and municipal level, surface water data are collected by highway departments, park commissions, water works, sanitary and sewer districts, and historical societies. Private and public corporations gathering hydrologic data are generally those that use large quantities of water in the industrial process and are, therefore, water-oriented. These include paper, electrical power, mining, cement, transportation, and recreation companies. Many local county and municipal agencies and the water-oriented industries are valuable sources for record flood level data. Significant data on record floods and droughts can also be found in records of newspapers, public libraries, and historical societies. When conducting an extensive and detailed hydrological study, all of these sources should be examined.

Analysis of data concerning surface water generated in the Canadian portion of the Great Lakes Basin is not within the scope of this report. These data are available in publications by the Inland Waters Branch, Department of Energy, Mines and Resources, Surface Water Data, Ontario.

1.2 U.S. Geological Survey Program

The basic data collection and analysis program of the Water Resources Division of the U.S. Geological Survey District offices represents the primary continuing effort in the United States portion of the Great Lakes Basin. Overall Federal effort for the collection of basic surface water hydrology data is coordinated by the Geological Survey's Office of Water Data Collection (OWDC) in Washington, D.C. This agency has published several summaries on the total data collection program in the United States. The district office of the Geological Survey located in each State in the Great Lakes Basin is responsible for the data collection program within that State. Stream gaging stations, which usually measure water-surface elevation, are used to collect basic data. Rating curves are developed for each station to relate measured water-surface elevation to the generally more useful stream discharge data. Rating curves are developed by measuring average stream velocities and cross-sectional areas and relating these data to concurring water-surface elevation. Because the cross-sectional regimen of many stations undergoes constant change, the rating curves are periodically readjusted to reflect the change.

1.3 Hydrologic Areas

In addition to showing the boundaries of planning subareas, the maps on Figures 2–1 through 2–15 are divided into several hydrologic areas coincident with the hydrologic areas and flood frequency regions delineated in the U.S. Geological Survey Water Supply Paper 1677. The hydrologic areas shown in this paper are delineated on the basis of drainage area and runoff characteristics. Flow-frequency determinations for each U.S. Geological Survey gaging station are available and on record in the files of the Great Lakes Basin Commission. The hydrologic area studies available from the U.S. Geological Survey are mentioned here for informational purposes only, in the event a more refined analysis of an area is desired.

1.4 Hydrologic Stations

As of January 1970, 648 long-term surface water stations were reported to be in operation in the Great Lakes region, including about 80 inland lake stations. Of this total, 551 are operated by the U.S. Geological Survey; 74 by the U.S. Army Corps of Engineers; 2 by the Forest Service, U.S. Department of Agriculture; 11 by the National Weather Service; 3 by the Minnesota Ore Operations, United States Steel Corporation; 5 by the Metropolitan Sanitary District of Greater Chicago; and one each by the Minnesota Power and Light Company and the Illinois Department of Public Works and Buildings. Not included are approximately 400 partial-record stations where streamflow data are obtained only during flood events or periods of low flow.

Activities reported by agencies other than the U.S. Geological Survey are usually those tailored to that agency's specific mission, such as reservoir management or hydroelectric purposes. However, those reported by the U.S. Geological Survey are activities in collaboration or cooperation with other agencies. The data from these activities are available to all water managers and users and are used for many purposes, such as the design of reservoirs, flood plain management, design and maintenance of navigational facilities, and correlation with water quality data. Table 2–1 lists by planning subarea existing hydrologic stations considered to be hydrologically representative of the drainage area and hydrologic area in which they are located. For the most part, the hydrological stations selected were U.S. Geological Survey stations having at least 15 years of record and not affected, or only slightly affected, by natural or artificial control, diversion, or regulation.

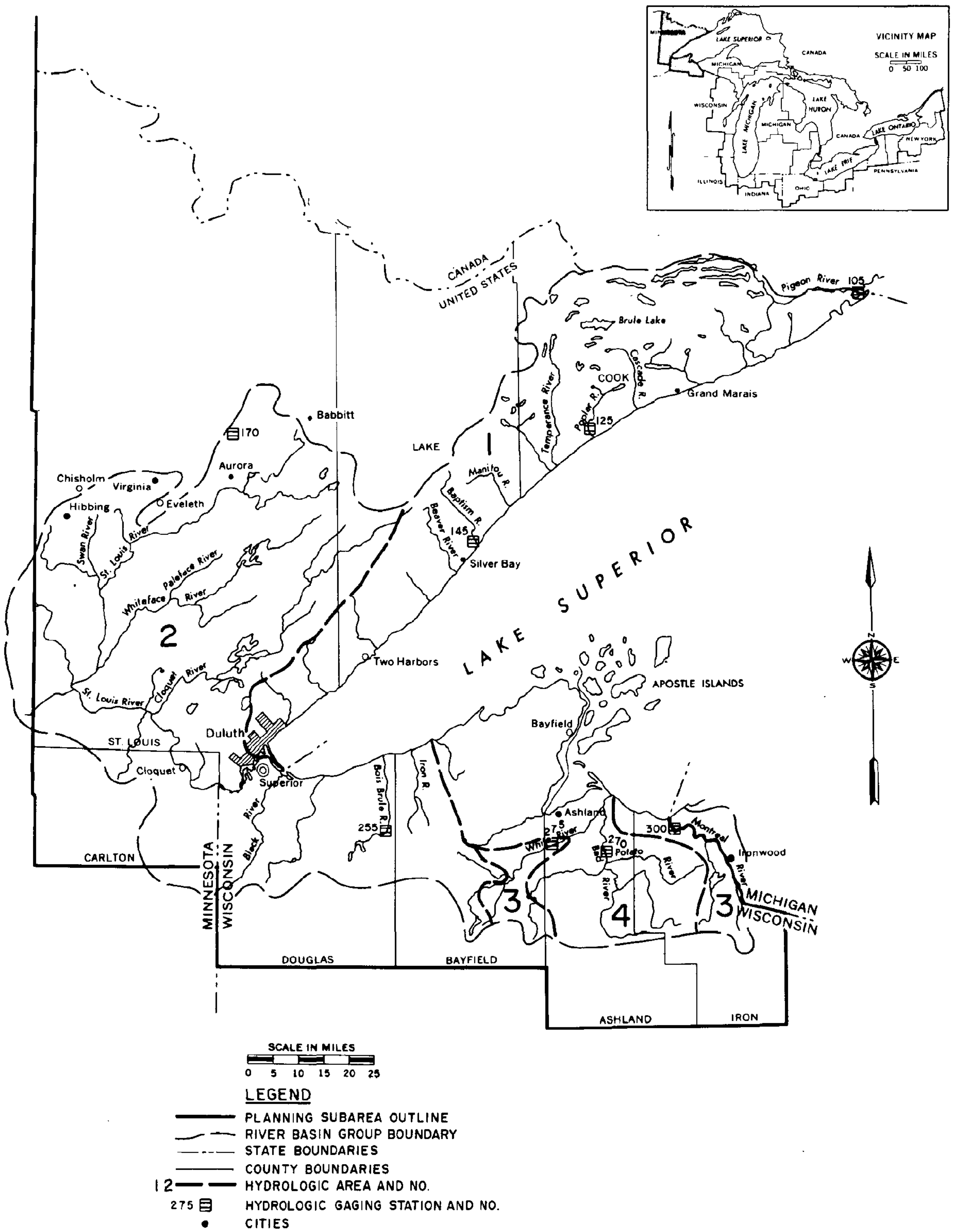


FIGURE 2-1 Hydrologic Gaging Stations, Planning Subarea 1.1

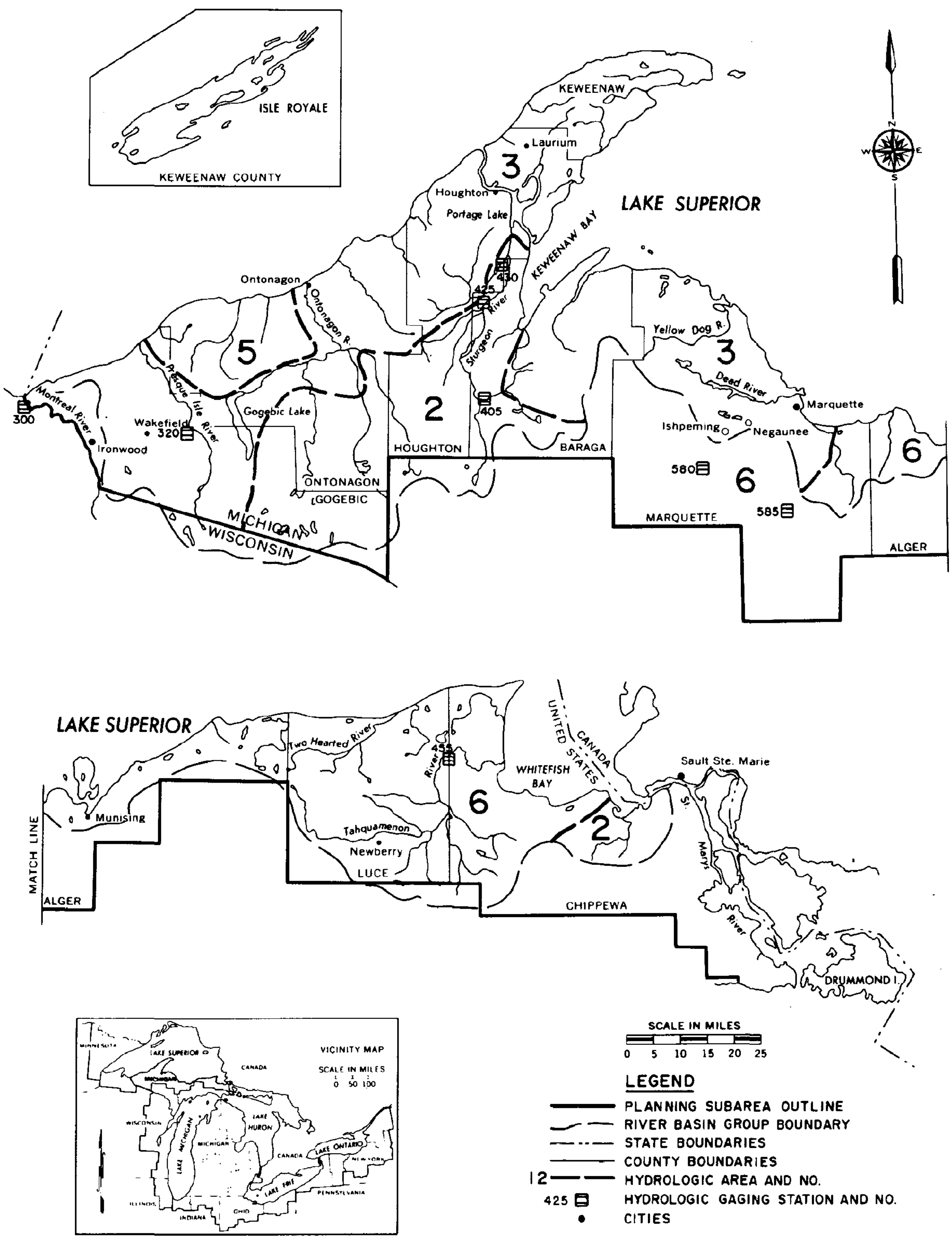


FIGURE 2-2 Hydrologic Gaging Stations, Planning Subarea 1.2

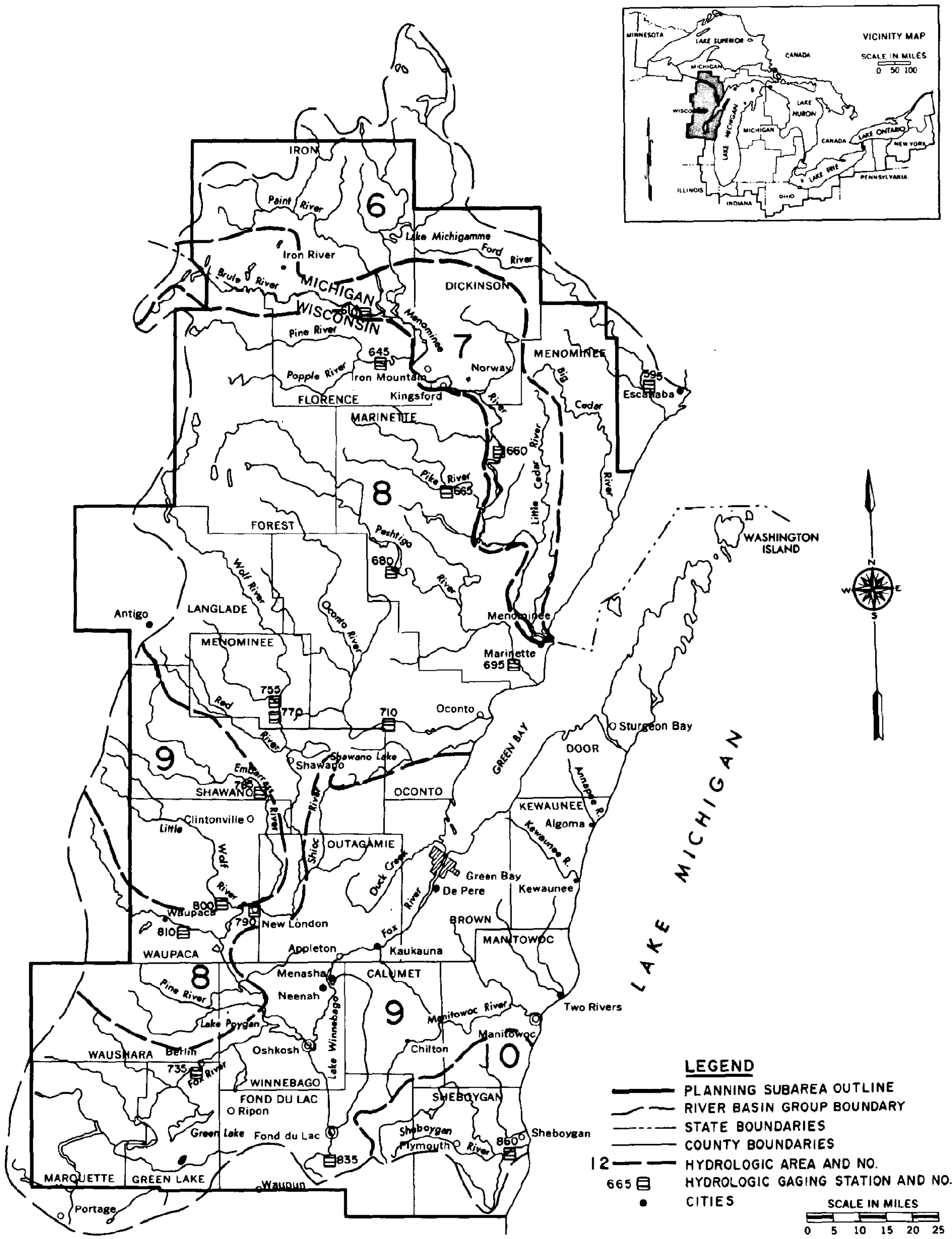


FIGURE 2–3 Hydrologic Gaging Stations, Planning Subarea 2.1

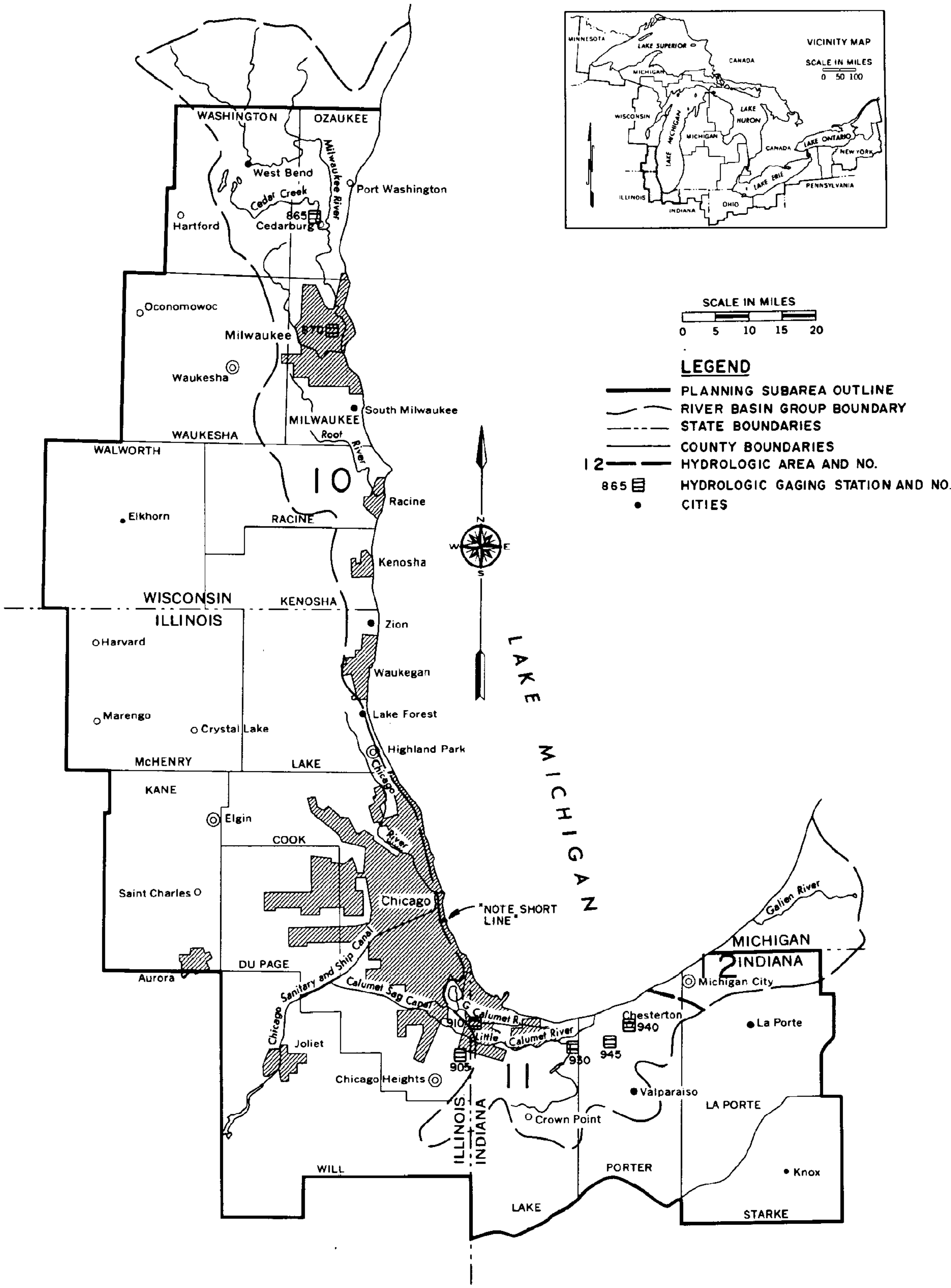


FIGURE 2-4 Hydrologic Gaging Stations, Planning Subarea 2.2

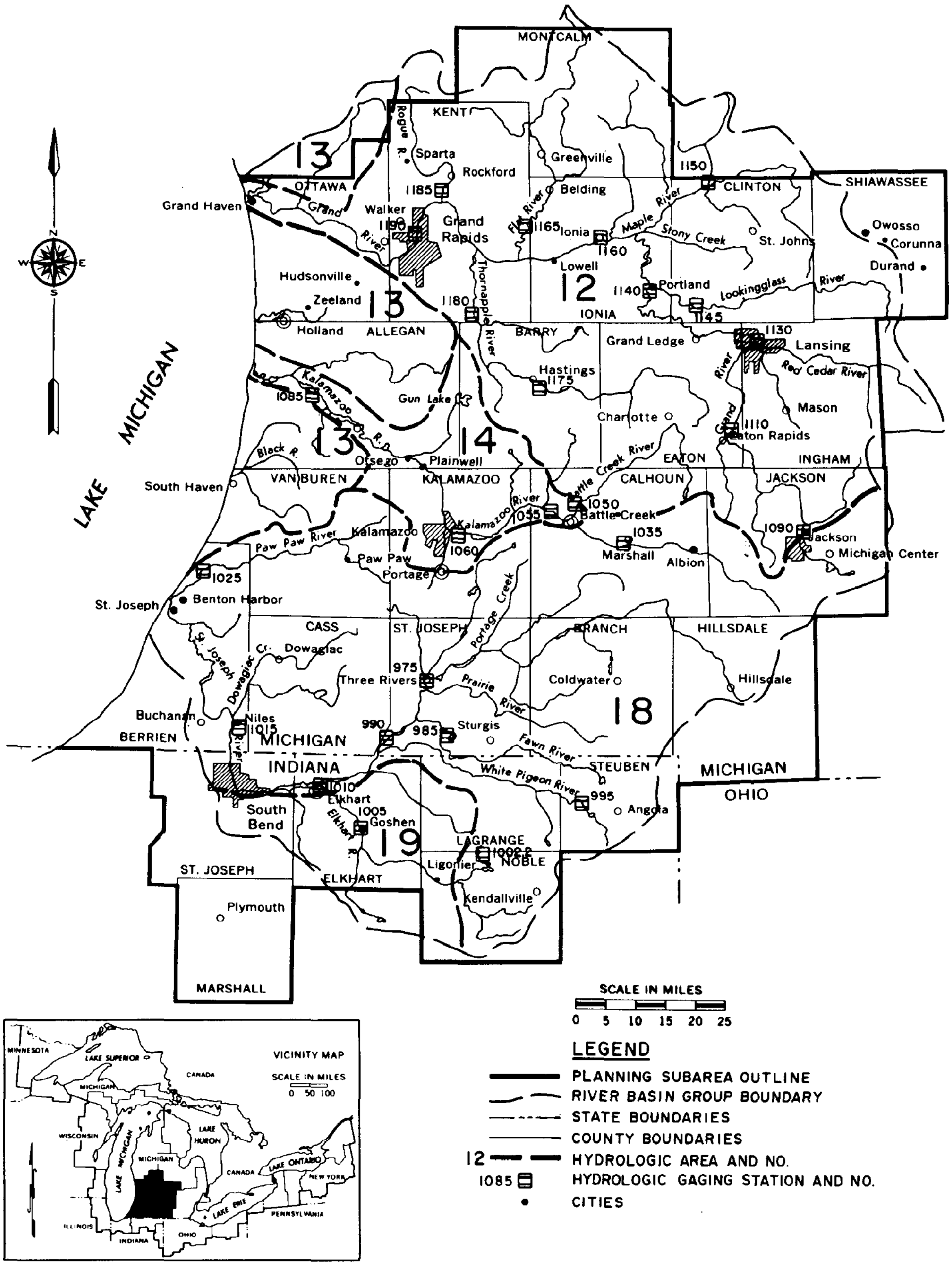


FIGURE 2-5 Hydrologic Gaging Stations, Planning Subarea 2.3

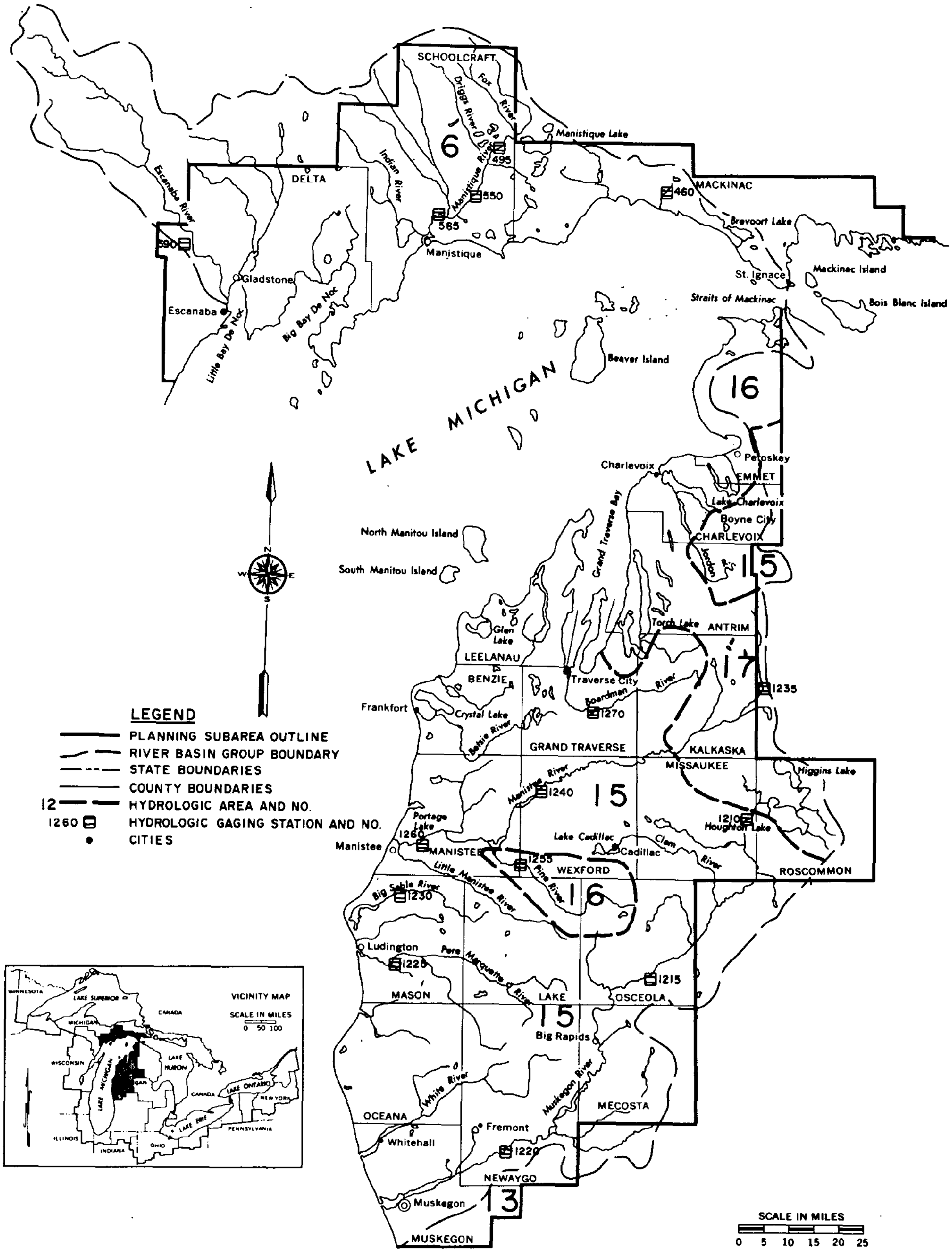


FIGURE 2–6 Hydrologic Gaging Stations, Planning Subarea 2.4

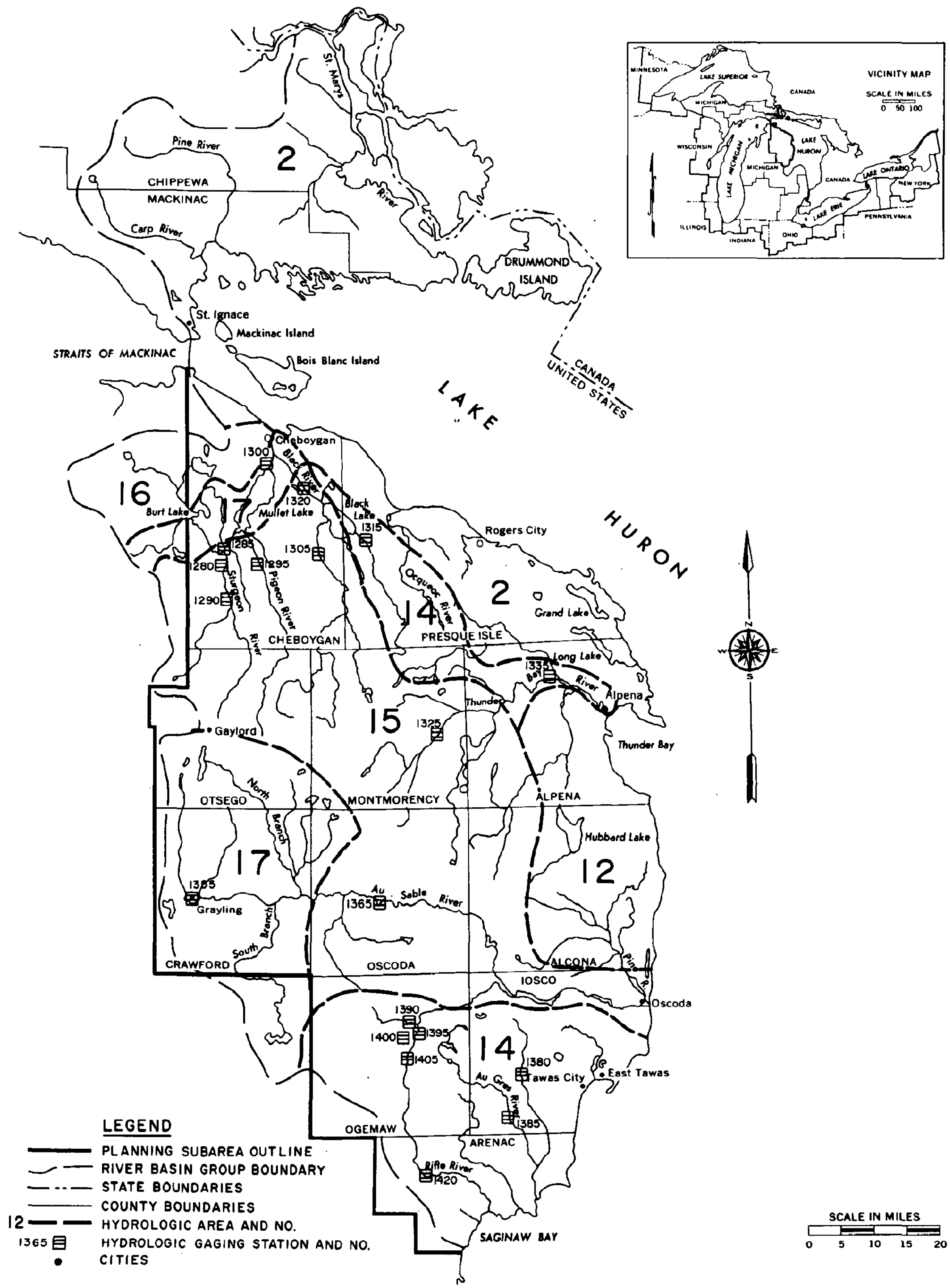


FIGURE 2-7 Hydrologic Gaging Stations, Planning Subarea 3.1

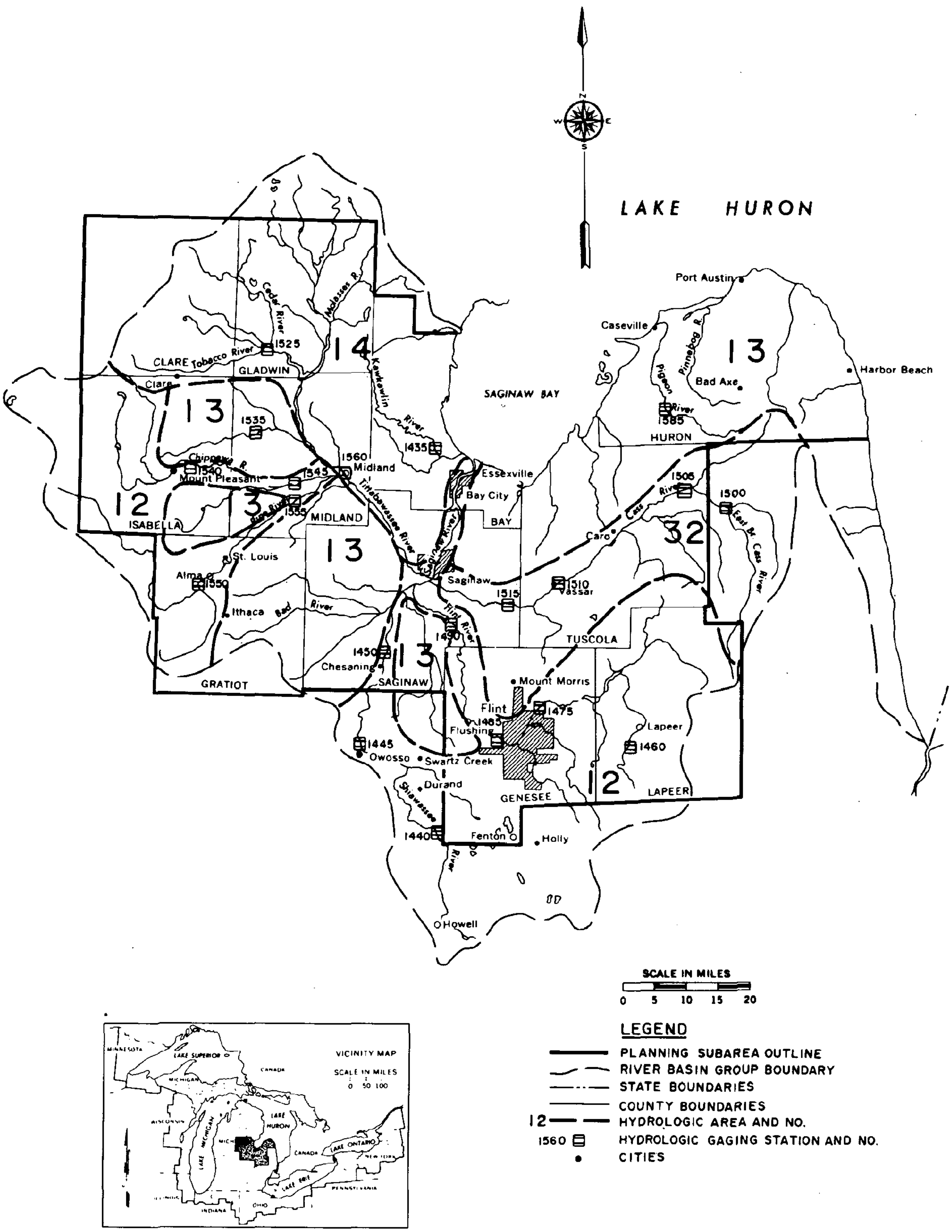


FIGURE 2–8 Hydrologic Gaging Stations, Planning Subarea 3.2

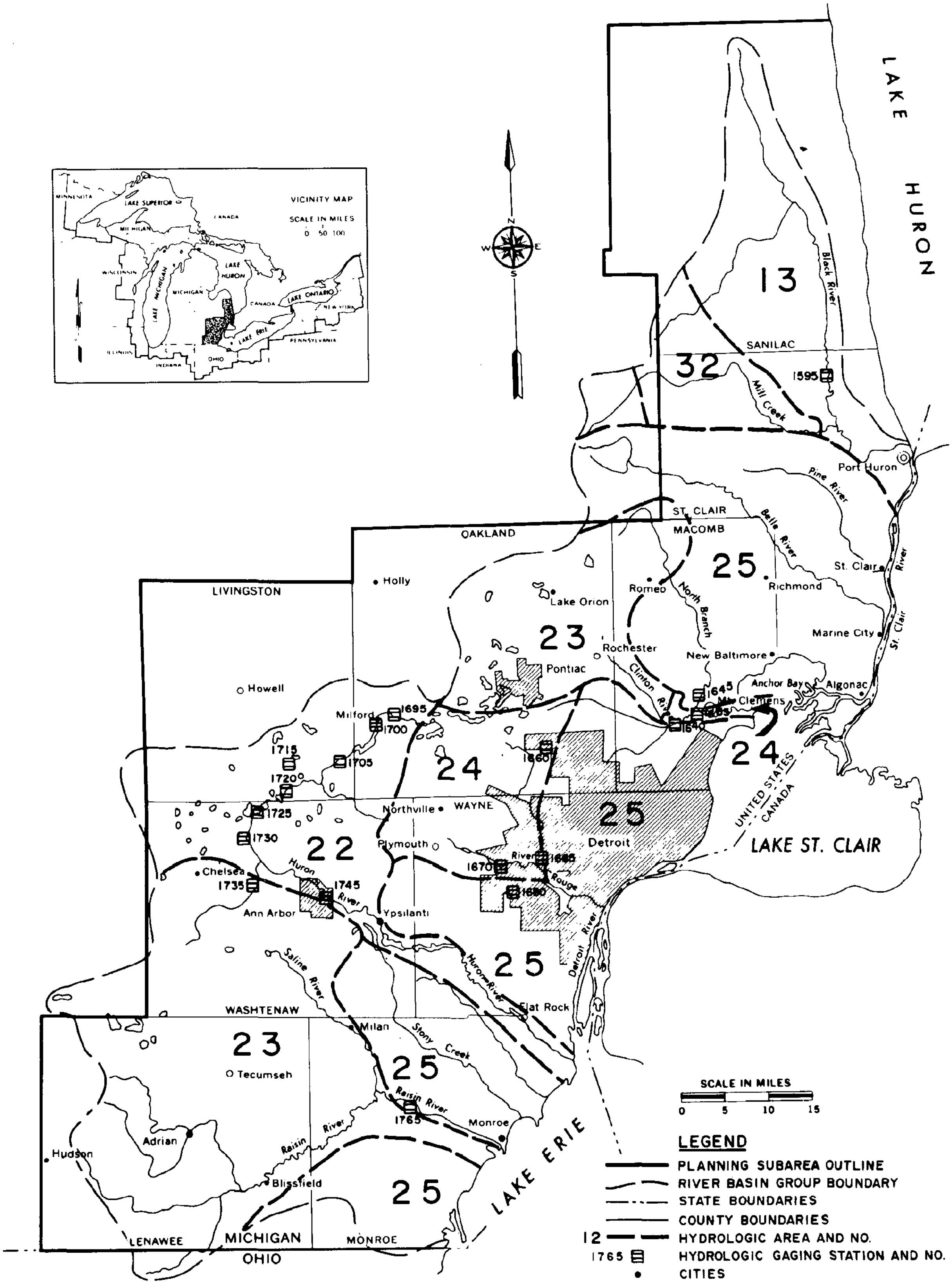


FIGURE 2-9 Hydrologic Gaging Stations, Planning Subarea 4.1

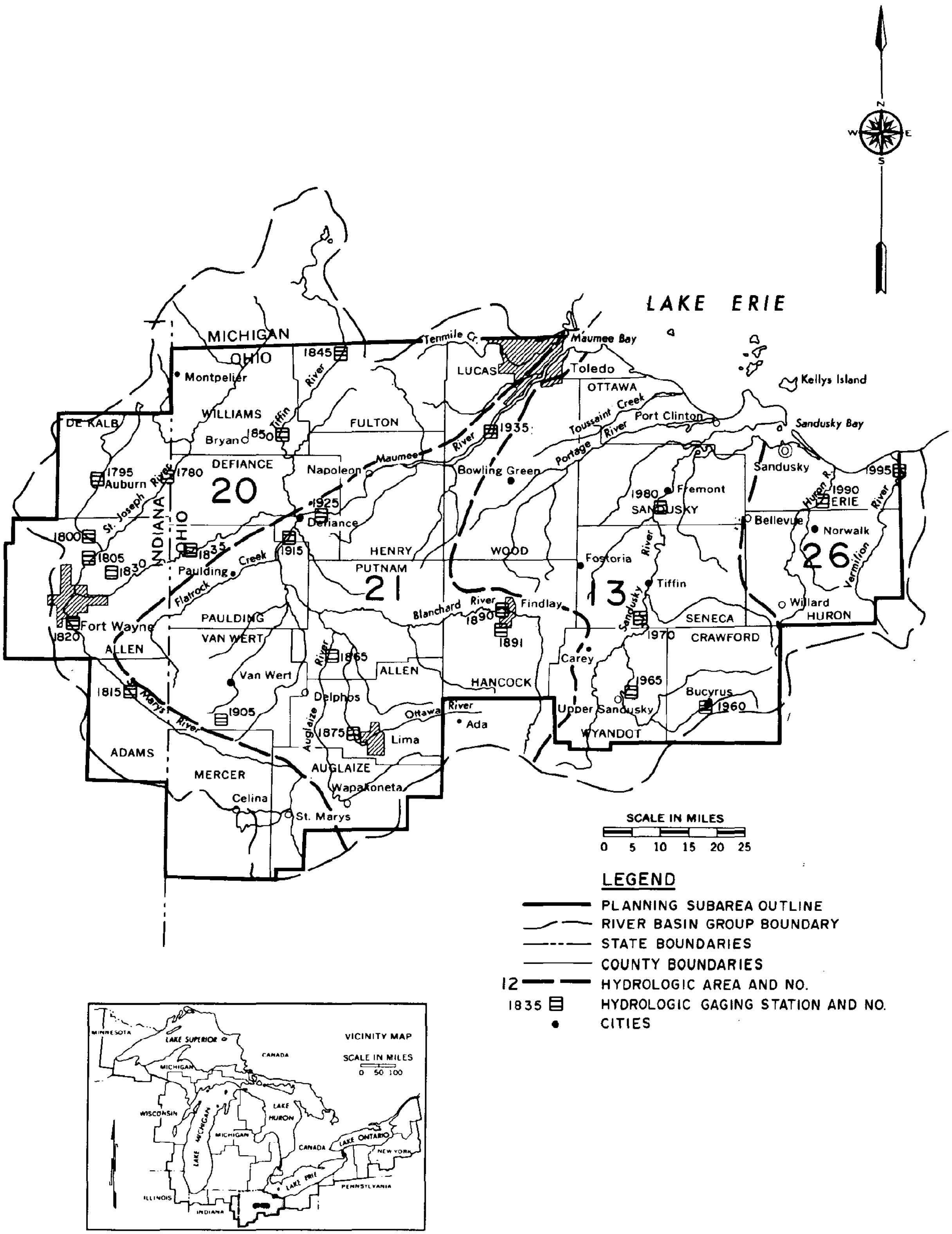


FIGURE 2–10 Hydrologic Gaging Stations, Planning Subarea 4.2

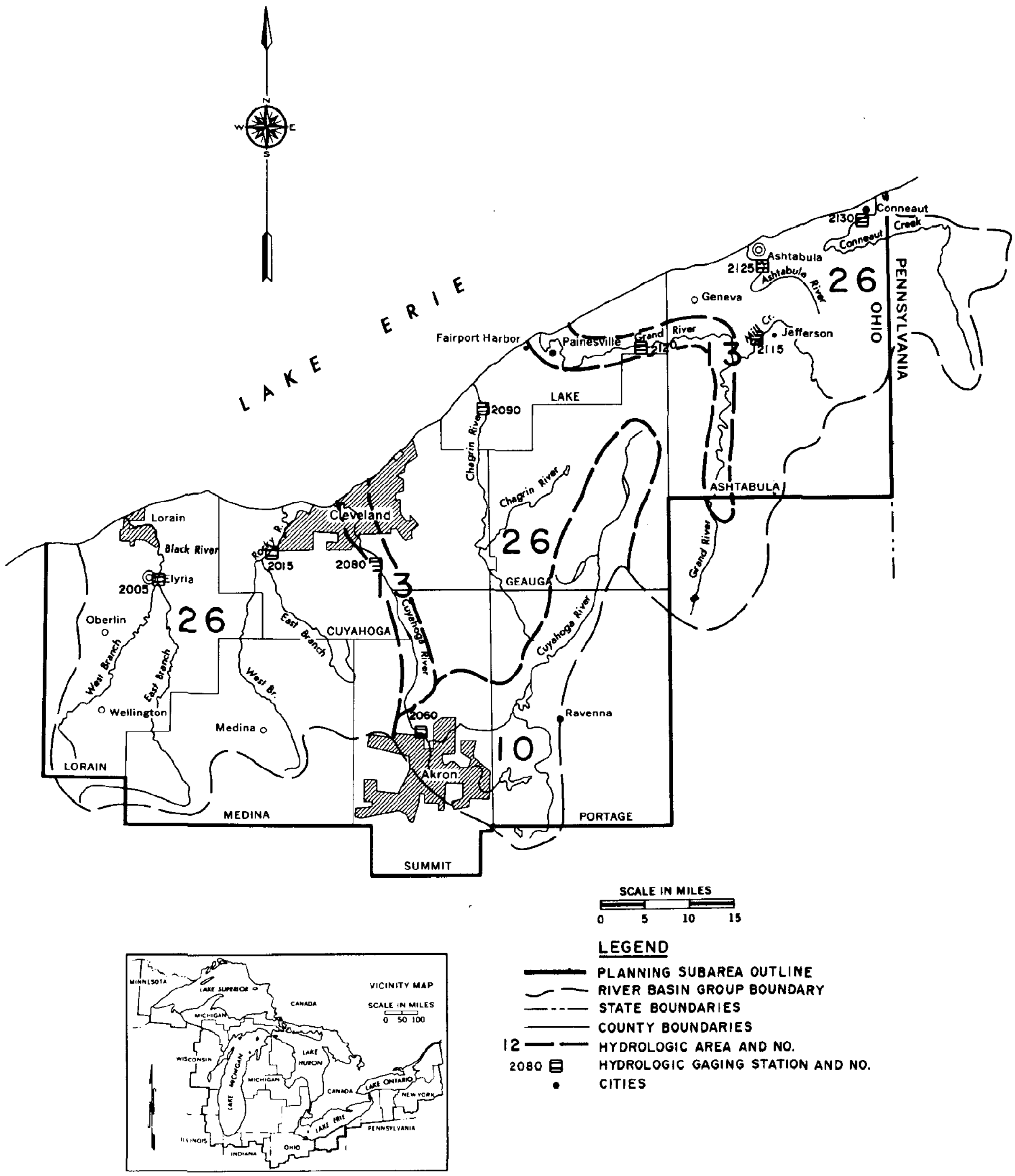


FIGURE 2-11 Hydrologic Gaging Stations, Planning Subarea 4.3

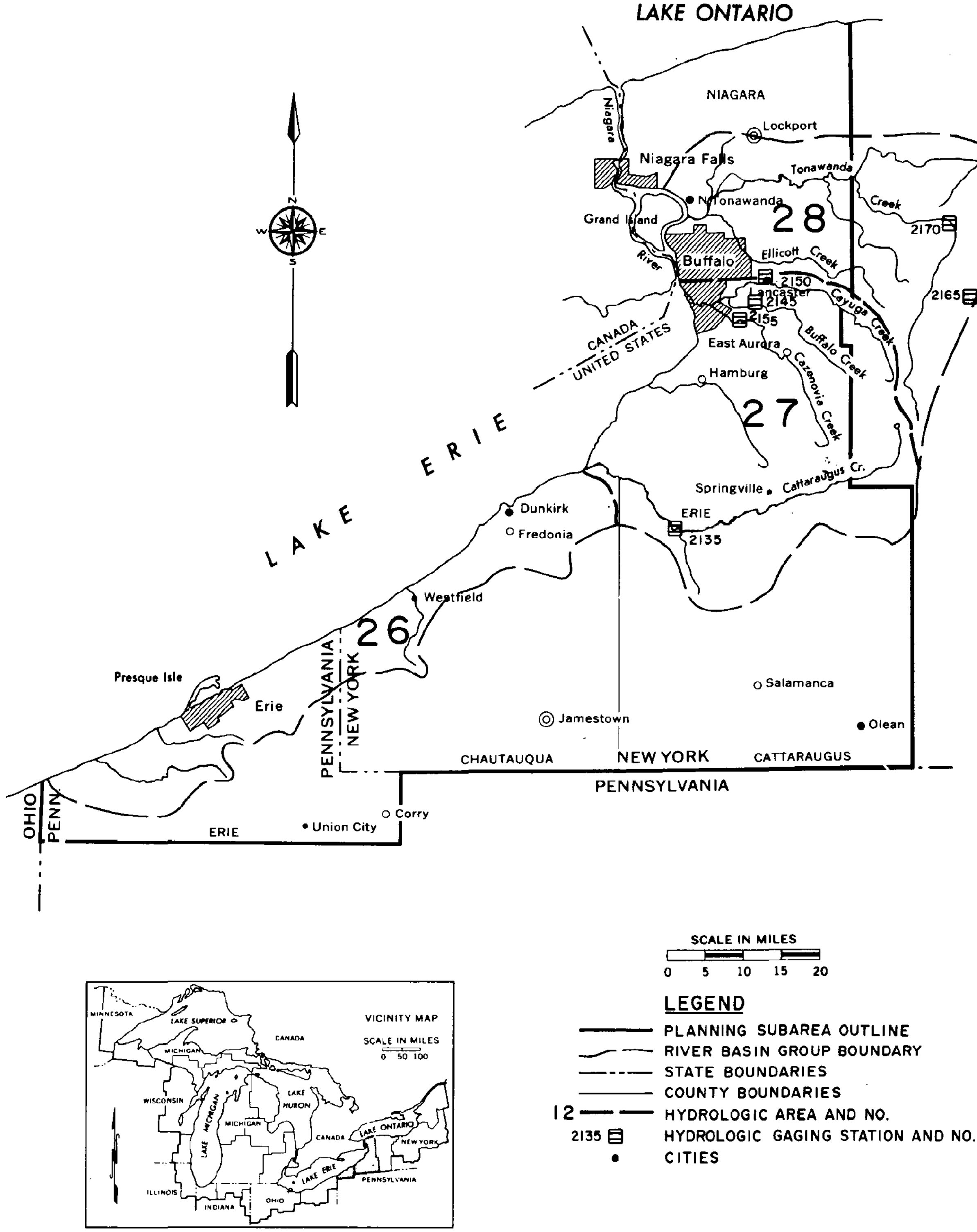


FIGURE 2-12 Hydrologic Gaging Stations, Planning Subarea 4.4

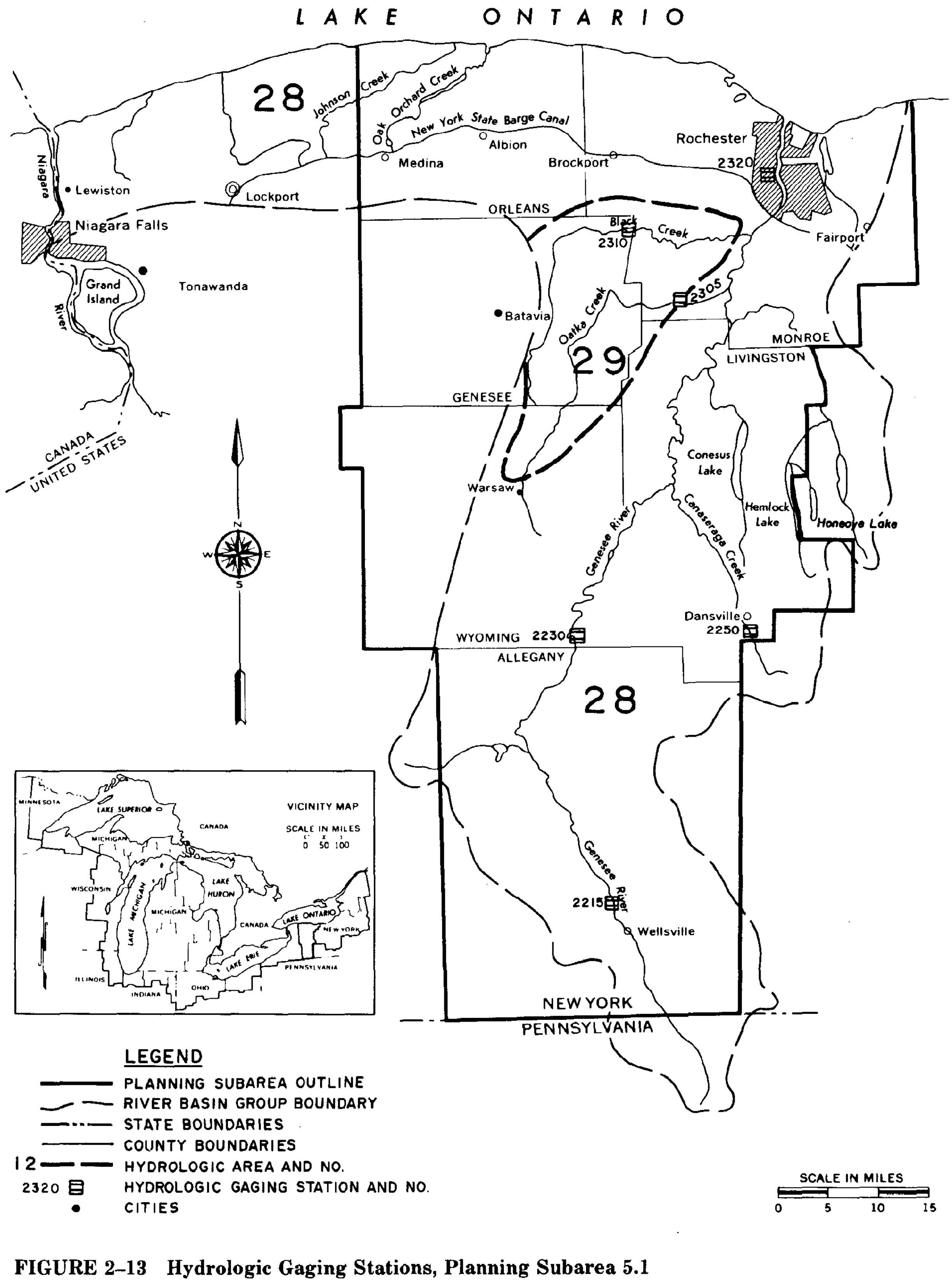


FIGURE 2–13 Hydrologic Gaging Stations, Planning Subarea 5.1

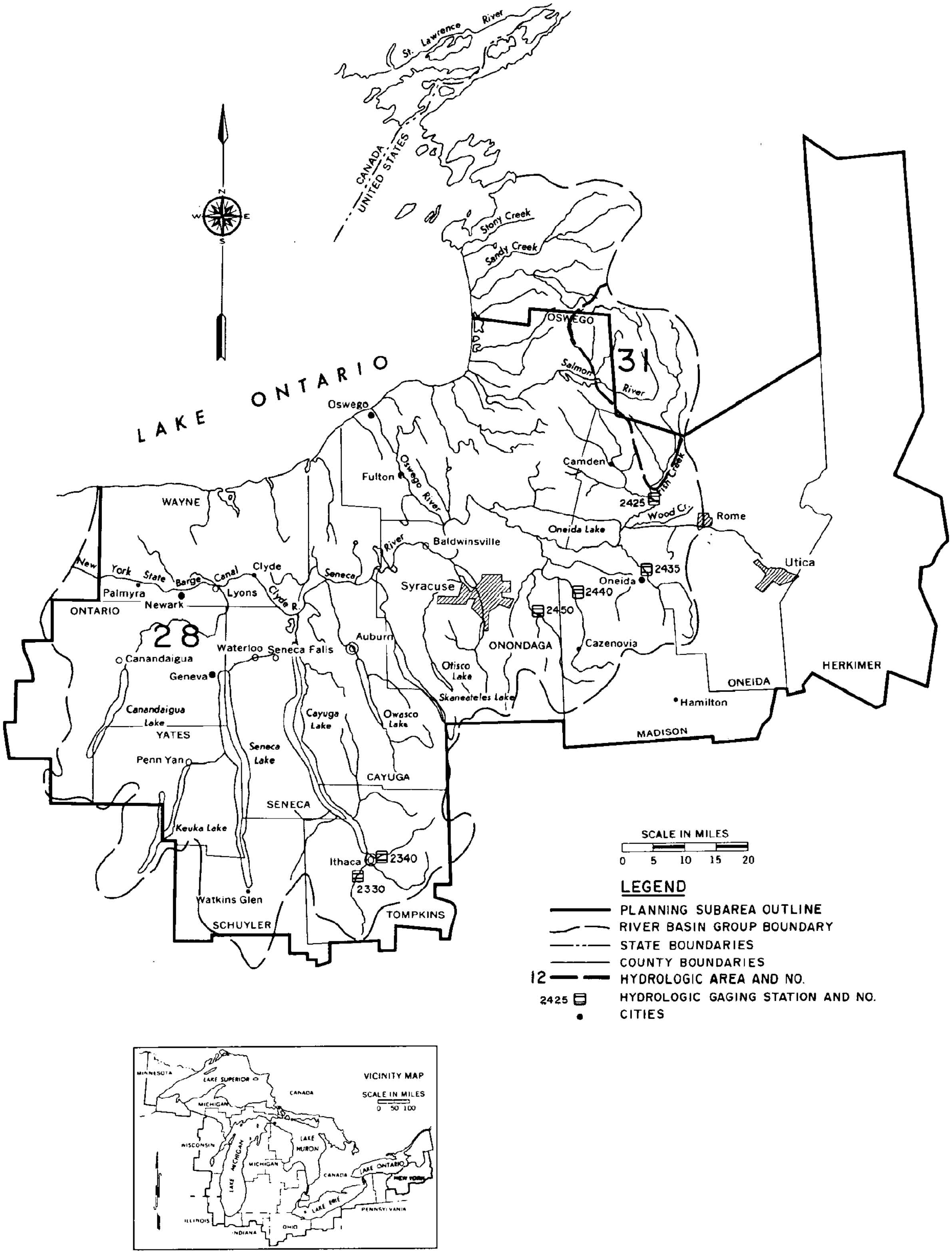


FIGURE 2–14 Hydrologic Gaging Stations, Planning Subarea 5.2

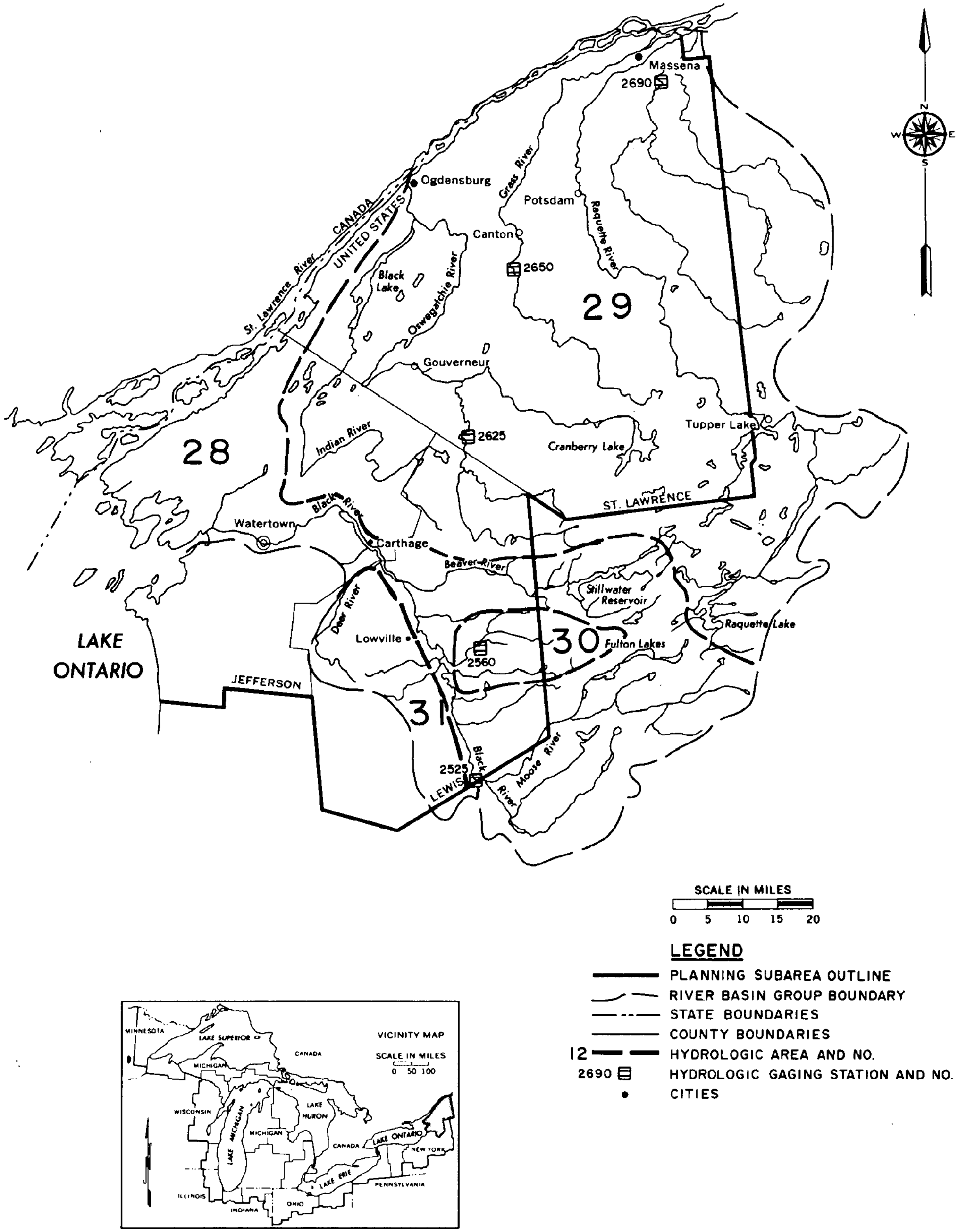


FIGURE 2–15 Hydrologic Gaging Stations, Planning Subarea 5.3

TABLE 2–1 Flow of Selected Stations

Station No. 4–	Stream and Station	Period of Record	Drainage Area (sq mi)	Average Discharge (cfs)	Monthly Mean Discharge Maximum (cfs)	Monthly Mean Discharge Minimum (cfs)	Annual Mean Discharge Maximum (cfs)	Annual Mean Discharge Minimum (cfs)
Lake Superior West--Planning Subarea 1.1								
105	Pigeon River Middle Falls, Minn.	1921-67	600	483	4,020	34	804	158
125	Poplar River Lutsen, Minn.	1911 1912-17 1928-47 1952-61	114	103	651	8	150	50
145	Baptism River Beaver Bay, Minn.	1927-67	140	159	1,800	2	259	82
170	Embarrass River Embarrass, Minn.	1942-64	93.8	64	782	1	119	31
255	Bois Brule River Brule, Wis.	1942-67	113	169	495	104	218	133
270	Bad River Odanah, Wis.	1914-22 1948-67	611	605	4,190	69	917	395
275	White River Ashland, Wis.	1948-67	269	291	1,020	147	426	218
300	Montreal River Saxon, Wis.	1938-67	262	325	1,790	21	487	166
Lake Superior East--Planning Subarea 1.2								
320	Presque Isle River near Tula, Mich.	1945-67	261	267	1,450	30	448	120
405	Sturgeon River near Sidnaw, Mich.	1912-15 1943-67	171	204	1,320	9	307	104
425	Otter River near Elo, Mich.	1942-67	162	212	1,210	76	289	154
430	Sturgeon River near Arnheim, Mich.	1942-67	705	807	3,930	234	1,072	520
455	Tahquamenon River near Paradise, Mich.	1953-67	790	865	4,510	201	1,281	616
Lake Michigan Northwest--Planning Subarea 2.1								
580	Middle Branch Escanaba River near Ishpeming, Mich.	1954-67	128	133	745	16.1	239.1	80.7
585	East Branch Escanaba River at Gwinn, Mich.	1954-67	124	98.7	592	22.0	198.7	57.4
590	Escanaba River at Cornell, Mich.	1903-12 1913-15 1950-67	870	896	4,330	14.1	1,385.0	493.7
595	Ford River near Hyde, Mich.	1954-67	450	341	2,480	34.8	640.0	183.3
610	Brule River near Florence, Wis.	1914-16 1944-67	389	347	1,240	174.0	450.1	232.2
645	Pine River at Pine River Power Plant near Florence, Wis.	1923-67	528	420	2,130	74.5	657.8	210.3
660	Menominee River near Pembine, Wis.	1949-67	3,240	2,922	12,100	1,200	4,318	1,877
665	Pike River at Amberg, Wis.	1914-67	253	216	1,020	78.1	344.4	133.4
680	Peshtigo River at High Falls near Crivitz, Wis.	1912-57	554	475	1,930	60.2	708.1	256.4
695	Peshtigo River at Peshtigo, Wis.	1953-67	1,124	852	4,640	285.0	1,518	591.1

TABLE 2–1(continued) Flow of Selected Stations

Station No. 4-	Stream and Station	Period of Record	Drainage Area (sq mi)	Average Discharge (cfs)	Monthly Mean Discharge Maximum (cfs)	Monthly Mean Discharge Minimum (cfs)	Annual Mean Discharge Maximum (cfs)	Annual Mean Discharge Minimum (cfs)
710	Oconto River near Gillett, Wis.	1906-09 1913-67	678	570	3,430	158	899.8	315.5
735	Fox River at Berlin, Wis.	1898-67	1,430	1,084	4,200	311	1,623	559.1
755	Wolf River above West Branch, Wolf River, Wis.	1927-62	633	569	1,890	235	840	390
770	Wolf River at Keshena Falls, Wis.	1907-67	812	753	2,530	294	1,109	510
785	Embarrass River near Embarrass, Wis.	1919-67	395	283	1,890	44.5	478.3	126.3
790	Wolf River at New London, Wis.	1896-67	2,240	1,701	9,170	429.0	2,810	865.5
800	Little Wolf River at Royalton, Wis.	1914-67	514	395	2,230	94.8	628.3	197.1
810	Waupaca River near Waupaca, Wis.	1916-66	272	236	615	111	299	159.6
835	East Branch Fond du Lac River at Fond du Lac, Wis.	1939-54	75	32	365	0.2	58.2	5.4
860	Sheboygan River at Sheboygan, Wis.	1916-24 1950-64	432	232	2,050	11.2	402.9	47.1
865	Cedar Creek near Cedarburg, Wis.	1930-67	121	62.7	522	1.4	159.4	13.5
870	Milwaukee River at Milwaukee, Wis.	1914-67	686	384	3,550	19.4	791.6	111.6
	Lake Michigan Southwest-Planning Subarea 2.2							
905	Thorn Creek at Thornton, Ill.	1948-67	104	90.3	372	12	126	69
910	Little Calumet River at South Holland, Ill.	1947-67	–	158	645	18	250	72
930	Deep River at Lake George Outlet at Hobart, Ill.	1947-67	125	93.6	477	6	170	34
940	Little Calumet River at Porter, Ind.	1945-67	62.9	68.6	414	20	110	35
945	Salt Creek near McCool, Ind.	1945-67	78.7	67.6	246	16	104	36
	Lake Michigan Southeast-Planning Subarea 2.3							
975	St. Joseph River at Three Rivers, Mich.	1953-67	1,350	919	2,830	187	1,472	365
985	Fawn River near White Pigeon, Mich.	1957-67	192	138	317	38	191	69
1015	St. Joseph River at Niles, Mich.	1930-67	3,666	3,040	13,600	828	5,718	1,464
1025	Paw Paw River at Riverside, Mich.	1951-67	390	384	1,040	158	600	270
1060	Kalamazoo River at Comstock, Mich.	1932-67	1,010	794	3,020	235	1,387	369
1085	Kalamazoo River near Fennville, Mich.	1929-67	1,600	1,301	5,000	285	2,074	737
1130	Grand River at Lansing, Mich.	1934-67	1,230	787	7,240	61	1,400	230
1190	Grand River at Grand Rapids, Mich.	1930-67	4,900	3,364	21,600	617	6,314	1,618

TABLE 2-1(continued) Flow of Selected Stations

Station No. 4-	Stream and Station	Period of Record	Drainage Area (sq mi)	Average Discharge (cfs)	Monthly Mean Discharge Maximum (cfs)	Monthly Mean Discharge Minimum (cfs)	Annual Mean Discharge Maximum (cfs)	Annual Mean Discharge Minimum (cfs)
Lake Michigan Northeast-Planning Subarea 2.4								
460	Black River near Garnet, Mich.	1951-67	28	26	147	6	46	16
495	Manistique River at Germfast, Mich.	1938-67	341	440	1,380	164	632	306
550	Manistique River near Blaney, Mich.	1938-67	704	820	3,580	227	1,273	499
565	Manistique River near Manistique, Mich.	1938-67	1,100	1,355	6,960	350	2,229	806
590	Escanaba River at Cornell, Mich.	1950-67	870	896	4,330	141	1,385	494
1210	Muskegon River near Merritt, Mich.	1946-67	309	221	743	27	319	136
1215	Muskegon River at Evart, Mich.	1933-67	1,450	953	3,840	316	1,424	613
1220	Muskegon River at Newaygo, Mich.	1930-67	2,350	1,907	5,840	595	2,599	1,119
1225	Pere Marquette River at Scottville, Mich.	1939-67	709	621	1,600	354	838	472
1230	Big Sable River near Freesoil, Mich.	1942-67	127	139	315	87	168	114
1235	Manistee River near Grayling, Mich.	1942-67	159	182	265	146	198	163
1240	Manistee River near Sherman, Mich.	1933-67	900	1,057	2,040	604	1,199	888
1255	Pine River near Hoxeyville, Mich.	1952-67	251	276	670	196	326	233
1260	Manistee River near Manistee, Mich.	1952-67	1,780	1,958	4,000	1,340	2,277	1,644
1270	Boardman River near Mayfield, Mich.	1952-67	223	190	383	124	229	163
Lake Huron North-Planning Subarea 3.1								
1300	Cheboygan River near Cheboygan, Mich.	1942-67	865	775	1,520	260	992	602
1325	Thunder Bay River near Hillman, Mich.	1945-67	232	208	545	119	252	171
1365	Au Sable River at Mio, Mich.	1952-67	1,100	926	1,970	578	1,113	746
1385	Au Gres River near National City, Mich.	1950-67	169	94	500	12	133	28
1420	Rifle River near Sterling, Mich.	1936-67	320	302	1,160	122	384	166
Lake Huron Central-Planning Subarea 3.2								
1440	Shiawassee River at Byron, Mich.	1947-67	368	238	1,380	26	431	72
1445	Shiawassee River at Owosso, Mich.	1931-67	538	308	1,950	13	591	95
1450	Shiawassee River near Fergus, Mich.	1939-67	637	394	2,560	41	688	118
1460	Farmers Creek near Lapeer, Mich.	1932-67	57	28	226	1	52	9
1485	Flint River near Flint, Mich.	1932-67	927	531	4,210	31	972	153

TABLE 2-1(continued) Flow of Selected Stations

Station No. 4-	Stream and Station	Period of Record	Drainage Area (sq mi)	Average Discharge (cfs)	Monthly Mean Discharge Maximum (cfs)	Monthly Mean Discharge Minimum (cfs)	Annual Mean Discharge Maximum (cfs)	Annual Mean Discharge Minimum (cfs)
Lake Huron Central-Planning Subarea 3.2 (continued)								
1500	S. Br. Cass River near Cass City, Mich.	1948–67	251	117	908	1	207	11
1505	Cass River at Cass City, Mich.	1947–67	370	190	1,500	1	340	28
1510	Cass River at Vassar, Mich.	1948–67	700	371	2,270	22	662	79
1515	Cass River at Frankenmuth, Mich.	1938–67	848	447	3,530	20	788	97
1525	Tobacco River at Beaverton, Mich.	1948–67	487	358	1,360	134	467	227
1535	Salt River near N. Bradley, Mich.	1934–67	138	76	636	4	172	21
1540	Chippewa River near Mt. Pleasant	1932–67	416	288	1,400	75	423	176
1545	Chippewa River near Midland, Mich.	1947–67	597	419	1,980	101	617	229
1550	Pine River at Alma, Mich.	1930–67	288	198	1,050	34	323	98
1555	Pine River near Midland, Mich.	1948–67	390	272	1,550	37	442	150
1560	Tittabawassee River at Midland, Mich.	1936–67	2,400	1,548	8,100	225	2,289	699
1585	Pigeon River near Owendale, Mich.	1952–67	55	27	194	2	47	5
Lake Erie Northwest-Planning Subarea 4.1								
1595	Black River near Fargo, Mich.	1944–67	475	271	2,340	5	512	29
1645	N. Br. Clinton River near Mount Clemens, Mich.	1947–67	199	108	790	2	208	25
1655	Clinton River at Mount Clemens, Mich.	1934–67	734	470	3,090	52	822	230
1660	River Rouge at Birmingham, Mich.	1950–67	37	14	98	1	25	5
1665	River Rouge at Detroit, Mich.	1930–67	185	104	965	6	203	26
1670	Middle River Rouge near Garden City, Mich.	1930–67	104	62	313	5	117	21
1680	Low. River Rouge at Inkster, Mich.	1947–67	83	46	294	1	99	16
1695	Huron River at Commerce, Mich.	1946–67	51	35	147	6	61	15
1700	Huron River at Milford, Mich.	1948–67	125	89	389	24	150	45
1705	Huron River near New Hudson, Mich.	1948–67	143	102	379	23	169	52
1715	Ore Creek near Brighton, Mich.	1951–67	31	21	68	3	32	11
1720	Huron River near Hamburg, Mich.	1951–67	299	184	895	42	286	97
1730	Huron River near Dexter, Mich.	1946–67	506	341	1,740	62	591	142
1735	Mill Creek near Dexter, Michigan	1952–67	134	63	281	11	87	30

TABLE 2–1(continued) Flow of Selected Stations

Station No. 4-	Stream and Station	Period of Record	Drainage Area (sq mi)	Average Discharge (cfs)	Monthly Mean Discharge Maximum (cfs)	Monthly Mean Discharge Minimum (cfs)	Annual Mean Discharge Maximum (cfs)	Annual Mean Discharge Minimum (cfs)
Lake Erie Northwest-Planning Subarea 4.1 (continued)								
1745	Huron River at Ann Arbor, Mich.	1948-67	711	431	2,230	74	812	186
1765	River Raisin near Monroe, Mich.	1937-67	1,034	659	4,680	4	1,374	178
Lake Erie Southwest-Planning Subarea 4.2								
1805	St. Joseph River near Fort Wayne, Ind.	1941-55	1,060	967	5,820	65	1,790	396
1820	St. Marys River near Fort Wayne, Ind.	1930-67	762	543	4,900	12	1,093	174
1835	Maumee River at Antwerp, Ohio	1921-67	2,128	1,625	11,600	79	3,459	389
1960	Sandusky River near Bucyrus, Ohio	1926-67	88.8	80.4	635	1.3	128	20.4
1965	Sandusky River near Upper Sandusky, Ohio	1922-67	298	233	1,700	1.2	392	70
1970	Sandusky River near Mexico, Ohio	1924-67	774	549	4,280	8.5	970	175
1980	Sandusky River near Fremont, Ohio	1924-67	1,251	906	7,660	9.9	1,551	275
1990	Huron River at Milan, Ohio	1951-67	371	267	1,580	5.8	430	145
1995	Vermilion River near Vermilion, Ohio	1951-67	262	214	1,510	0.0	352	102
Lake Erie Central-Planning Subarea 4.3								
2005	Black River at Elyria, Ohio	1945-67	396	296	1,830	2.3	470	130
2015	Rocky River near Berea, Ohio	1925-67	267	242	1,400	1.2	418	79
2060	Cuyahoga River at Old Portage, Ohio	1922-67	404	403	1,807	47	669	181
2080	Cuyahoga River at Independence, Ohio	1922-67	707	737[a]	3,585	61	1,173	278
2090	Chagrin River at Willoughby, Ohio	1925-67	246	311	1,412	19	451	149
2115	Mill Cr. near Jefferson, Ohio	1942-66	82	105	481	0.0	159	65
2120	Grand River near Madison, Ohio	1923-67	581	646	3,600	2.7	1,080	323
2125	Ashtabula River near Ashtabula, Ohio	1925-67	121	146	653	0.0	210	85
2130	Conneaut Cr. at Conneaut, Ohio	1923-67	175	240	1,050	2.8	367	140
Lake Erie East-Planning Subarea 4.4								
2135	Cattaraugus Cr. at Gowanda, N.Y.	1941-67	432	696	3,820	78	1,027	536
2145	Buffalo Cr. at Gardenville, N.Y.	1939-67	144	182	1,050	6.2	277	128
2150	Cayuga Cr. near Lancaster, N.Y.	1939-67	95	120	680	1.1	206	78
2155	Cazenovia Cr. at Ebenezer, N.Y.	1941-67	134	213	1,060	6.1	316	163

TABLE 2-1(continued) Flow of Selected Stations

Station No. 4-	Stream and Station	Period of Record	Drainage Area (sq mi)	Average Discharge (cfs)	Monthly Mean Discharge Maximum (cfs)	Monthly Mean Discharge Minimum (cfs)	Annual Mean Discharge Maximum (cfs)	Annual Mean Discharge Minimum (cfs)
Lake Erie East-Planning Subarea 4.4 (continued)								
2165	Little Tonawanda Cr. at Linden, N.Y.	1913-67	22	27	196	0.2	46	17
2170	Tonawanda Cr. at Batavia, N.Y.	1945-67	171	188	1,210	5.6	299	124
Lake Ontario West-Planning Subarea 5.1								
2215	Genesee R. at Scio, N.Y.	1917-67	308	380	2,620	16	602	227
2230	Genesee R. at Portageville, N.Y.	1909-67	981	1,204	7,780	64	2,040	766
2250	Canaseraga Cr. near Dansville, N.Y.	1911-67	153	149	1,030	15	277	81
2275	Genesee River at Jones Bridge	1909-13 1916-67	1,417	1,600	10,000	83	2,641	972
2305	Oatka Cr. at Garbutt, N.Y.	1946-67	204	187	1,070	17	315	117
2310	Black Cr. at Churchville, N.Y.	1946-67	123	98	609	1.7	177	52
2320	Genesee River at Driving Park, N.Y.	1921-67	2,457	2,682	14,300	152	4,237	1,666
Lake Ontario Central-Planning Subarea 5.2								
2330	Cayuga Inlet near Ithaca, N.Y.	1938-67	37	37	248	3.0	59	15
2340	Fall Cr. near Ithaca, N.Y.	1926-67	126	179	1,040	7.1	254	84
2425	East Br. Fish Cr. at Taberg, N.Y.	1924-67	188	526	2,730	29	909	356
2435	Oneida Cr. at Oneida, N.Y.	1950-67	113	144	596	18	209	100
2440	Chittenango Cr. near Chittenango, N.Y.	1951-67	66	106	577	14	147	66
2450	Limestone Cr. at Fayetteville, N.Y.	1941-67	86	132	599	16	202	71
Lake Ontario East-Planning Subarea 5.3								
2525	Black R. near Boonville, N.Y.	1912-67	295	667	3,000	42	1,044	448
2560	Independence R. at Donnattsburg, N.Y.	1943-67	92	181	794	23	292	132
2625	West Br. Oswegatchie R. near Harrisville, N.Y.	1917-67	258	498	2,260	37	833	333
2650	Grass R. at Pyrites, N.Y.	1925-67	335	586	2,550	70	1,107	353
2690	St. Regis R. at Brasher Center, N.Y.	1911-67	616	1,018	4,530	129	1,880	581

[a]Does not include discharge of Ohio Canal (approximately 64 cfs).

NOTE: Runoff (inches per year) = $13.6 \times \left(\frac{\text{Mean annual discharge (cfs)}}{\text{Drainage area (sq mi)}}\right)$.

Section 2

RUNOFF ANALYSIS

2.1 General

Nearly all surface water runoff from tributary streams in the Great Lakes Basin is supplied from precipitation falling within its boundaries. Only minor contributions to runoff come from municipal and industrial withdrawals of water from subsurface aquifers whose sources are outside the Basin. The average annual runoff within the study area is 11.6 inches or nearly 63.2 billion gallons per day. The influence of the Great Lakes together with bordering highlands is responsible for variations in areal and seasonal distribution of precipitation over the Basin. Areas on the downwind side of a Lake normally receive greater amounts of precipitation as snowfall in the winter than areas on the upwind side. The influence of the Great Lakes produces a climate that is more moderate than that of other areas at the same latitude. The wide variation in runoff among the planning subareas is primarily due to differences in geology, surficial features, climate, and land use rather than to differences in annual precipitation. In those portions of Planning Subareas 1.1, 1.2, and 2.1 that include the Upper Peninsula of Michigan, runoff records on several streams have been influenced by pumped mine-drainage water that would naturally be held in ground-water storage. Natural flows have also been modified by operation of storage reservoirs for hydroelectric power projects. Major streams affected by augmented flows include the upper St. Louis River in Minnesota, the Menominee River in Wisconsin, and the Montreal and Iron Rivers in Michigan. Caution should be used when analyzing past flow records on such streams in view of a reduction in mining operations in recent years. Although augmented flows would have little impact on high-flow records, drought-flow records would be significantly affected. For example, in Iron County, Michigan, approximately 15 cfs (cubic feet per second) were pumped from the mines (October 1965) and would be included in the flow at Station No. 610 in Table 2–1. Several references concerning ground-water pumping in upper Michigan are listed in the Bibliography.

2.2 Monthly Distribution of Runoff

Monthly distribution of runoff for a representative selected hydrologic station in each planning subarea is shown graphically in Figures 2–16 through 2–19. The graphs show the maximum, average, and minimum monthly discharges. The upper graph represents the maximum monthly flow for each of the 12 months during the period of record, and the lower graph represents the minimum monthly flow for each month during the period of record. Table 2–2 summarizes the average monthly discharge, evaluated for additional hydrologic stations in the planning subareas. The data on monthly maximum and minimum discharges for these stations are available in working papers filed at the office of the Great Lakes Basin Commission. The distribution of runoff generally reflects seasonal variations of temperature and precipitation that produce the cycle of snow accumulation in winter and snowmelt runoff in spring.

2.3 Annual Runoff

Average annual runoff for major United States tributaries of the Great Lakes Basin varies from 9 to 38 inches, with the average for the entire Basin being 11.6 inches. Of the major streams analyzed, the maximum annual runoff, 65.6 inches, occurred on East Branch Fish Creek, New York, and the minimum annual runoff, 2.5 inches, occurred in the Maumee River basin in Ohio. Annual mean runoff data for selected hydrologic stations are shown in Table 2–1. This table shows the average annual discharge, maximum annual mean discharge, and minimum annual mean discharge for each station. The annual runoff is dependent primarily upon precipitation but is significantly influenced by temperature, vegetation, terrain, surficial features, land use, and geology. The formula for converting discharge to inches of runoff is:

$$\text{Runoff (in/yr)} = 13.6 \text{ X} \left[\frac{\text{mean annual discharge (cfs)}}{\text{drainage area (sq mi)}}\right]$$

2.4 Flow Duration

One of the basic hydrologic tools for analyzing runoff rates is the flow-duration curve. This curve is a graphical expression of the percent of time streamflow will exceed an identified discharge. Because flow duration is a refinement beyond the intended scope of framework study analysis, flow-duration data are not included in this appendix. However, the U.S. Geological Survey has developed these data as a part of the statistical summary papers for each station reported in the Water Supply Papers. If flow-duration data are required for detailed hydrologic studies of water supply potential for power, irrigation, and industrial or municipal-domestic use, they can be obtained from the district office of the U.S. Geological Survey responsible for records of the station being studied.

2.5 Runoff Volumes

Runoff volume for hydrologic surface water stations can be expressed as an average rate of flow for a specific period of time. Tables 2–1 and 2–2 plus Figures 2–16 through 2–19 show volume data for selected stations in each planning subarea in average rate of flow for a specific duration. Runoff volumes can also be expressed as a cumulative running total of mean monthly discharge for a continuous period of record. The resulting curve, the mass runoff curve, can be used in water availability, yield, and storage studies. Mass curves are further discussed in Section 5, Surface Water Availability Studies.

2.6 Infiltration Rate and Base Streamflow

The ability of a given soil to absorb a continuous, heavy rainfall rapidly decreases until a uniform minimum rate of infiltration is reached. Infiltration rates will vary considerably depending on location in the Basin, geology and soil types, land use and cover, slope, and the like. At the same location, infiltration rates will change as permeability does because of variation in temperature of soil and rainfall, cover, intensity of rainfall, and other antecedent conditions. Initial losses and infiltration rates used for hydrologic analysis are usually determined from reconstruction of rainfall-runoff relationships of past storms.

Initial losses and infiltration rates used for hydrologic analysis by the Soil Conservation Service for upstream watersheds are based on a study of the soils, land use, and treatment classes illustrated in its National Engineering Handbook. The major soils in the United States have been classified into four groups, A, B, C, and D, with A having the highest infiltration potential and D the lowest. Studies of infiltration rate and base streamflow are important when evaluating the percentage of precipitation that is available for streamflow runoff, ground-water accretion, seasonal low flows, and drought flows. Specific studies to numerically evaluate infiltration rates for the various planning subareas are beyond the basic methodologies developed for this framework report. However, full consideration should be given to infiltration losses when detailed hydrologic analysis is required.

Base streamflow is the relatively stable streamflow fed by ground-water sources, which in turn are replenished by infiltration. Base flow varies with precipitation. Base flow constitutes almost all streamflow during dry periods but only a fraction of streamflow during and following floods and spring snowmelt. The smaller of the monthly average flow values shown in Table 2–2 for selected hydrologic stations in each planning subarea can be used as an indication of normal or average low base flow. The minimum monthly discharge values shown in Table 2–1 represent an approximation of minimum base flow at each station.

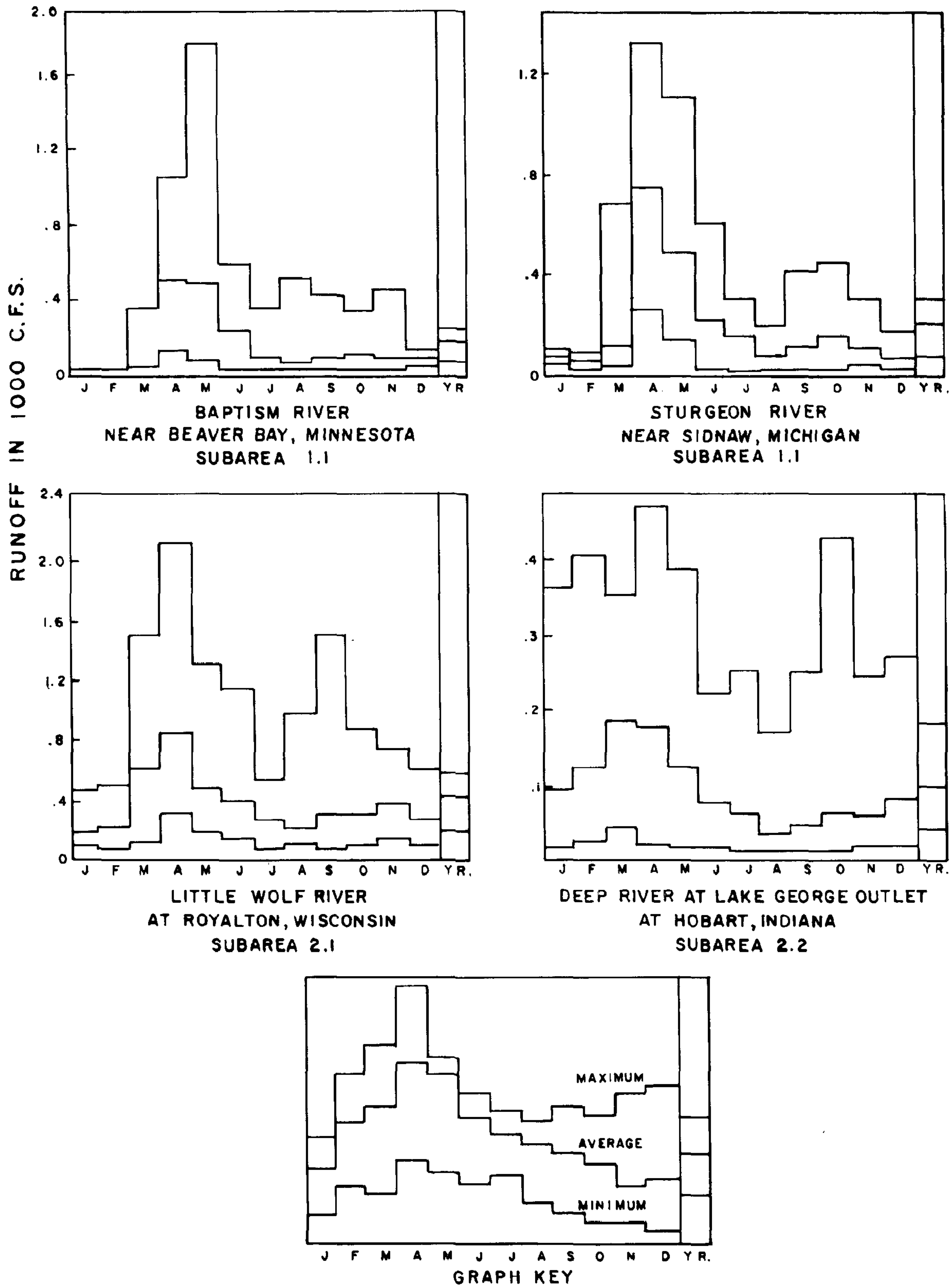


FIGURE 2-16 Monthly Distribution of Runoff, Planning Subareas 1.1, 1.2, 2.1, and 2.2

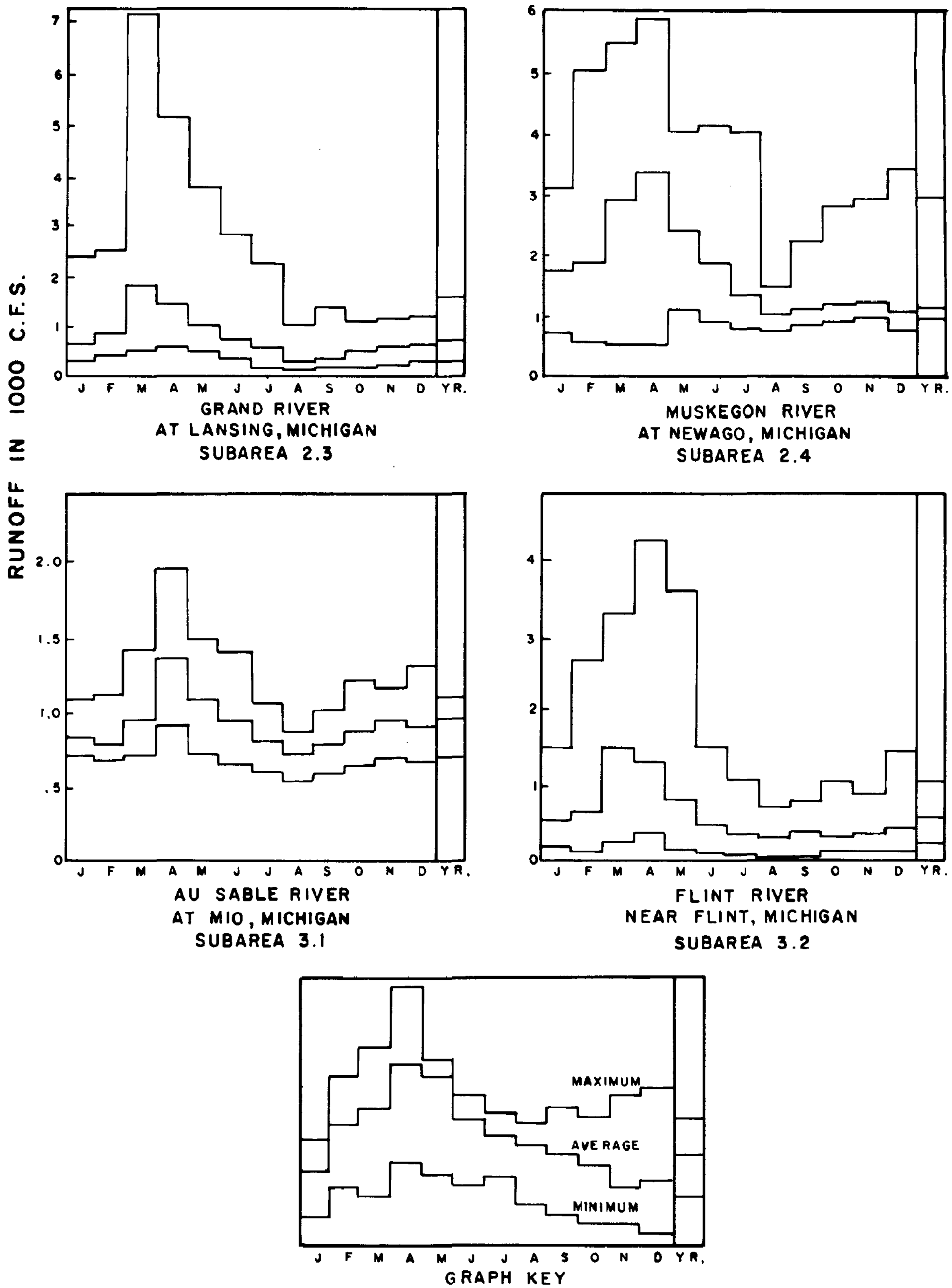


FIGURE 2-17 Monthly Distribution of Runoff, Planning Subareas 2.3, 2.4, 3.1, and 3.2

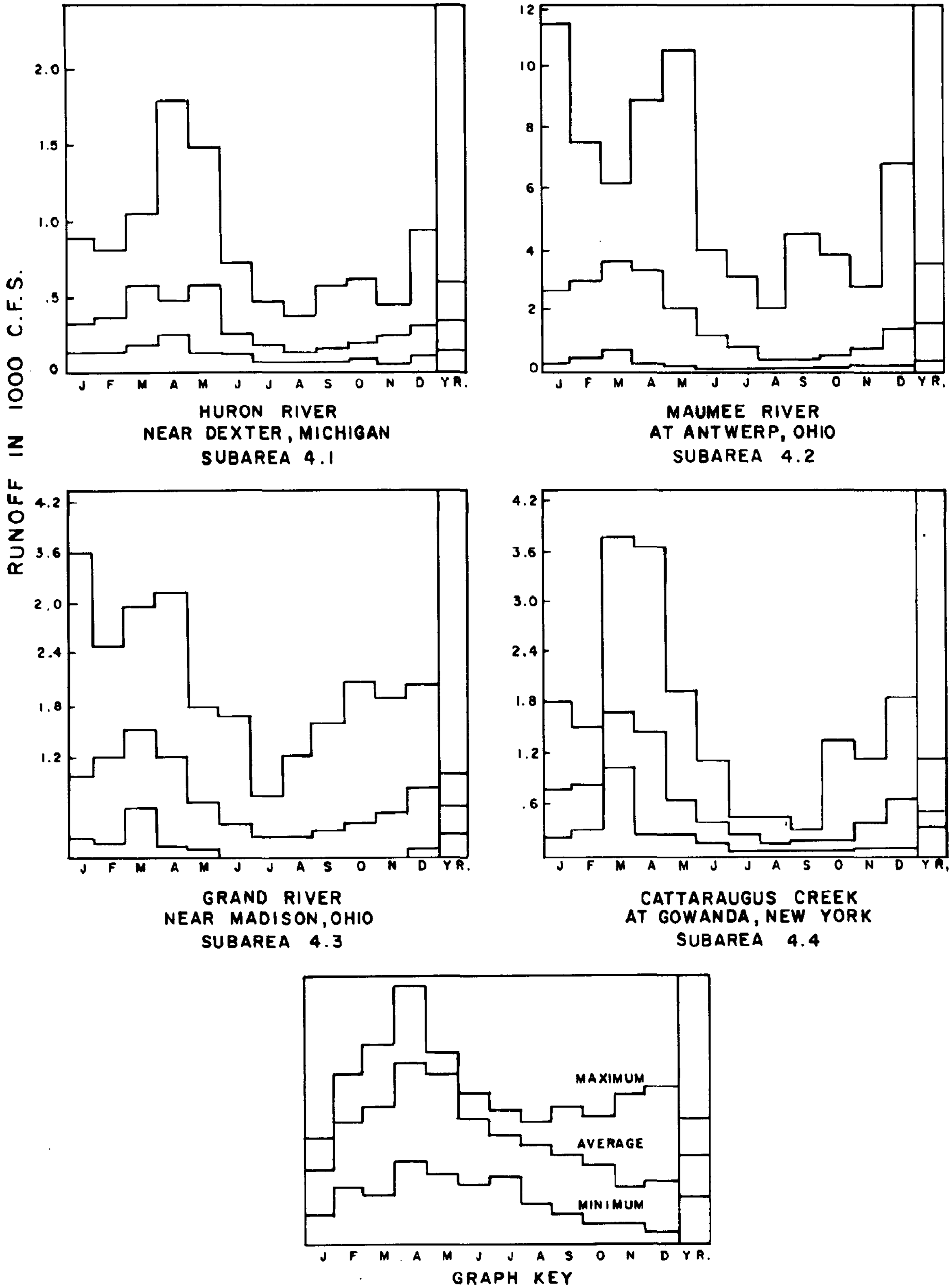


FIGURE 2-18 Monthly Distribution of Runoff, Planning Subareas 4.1, 4.2, 4.3, and 4.4

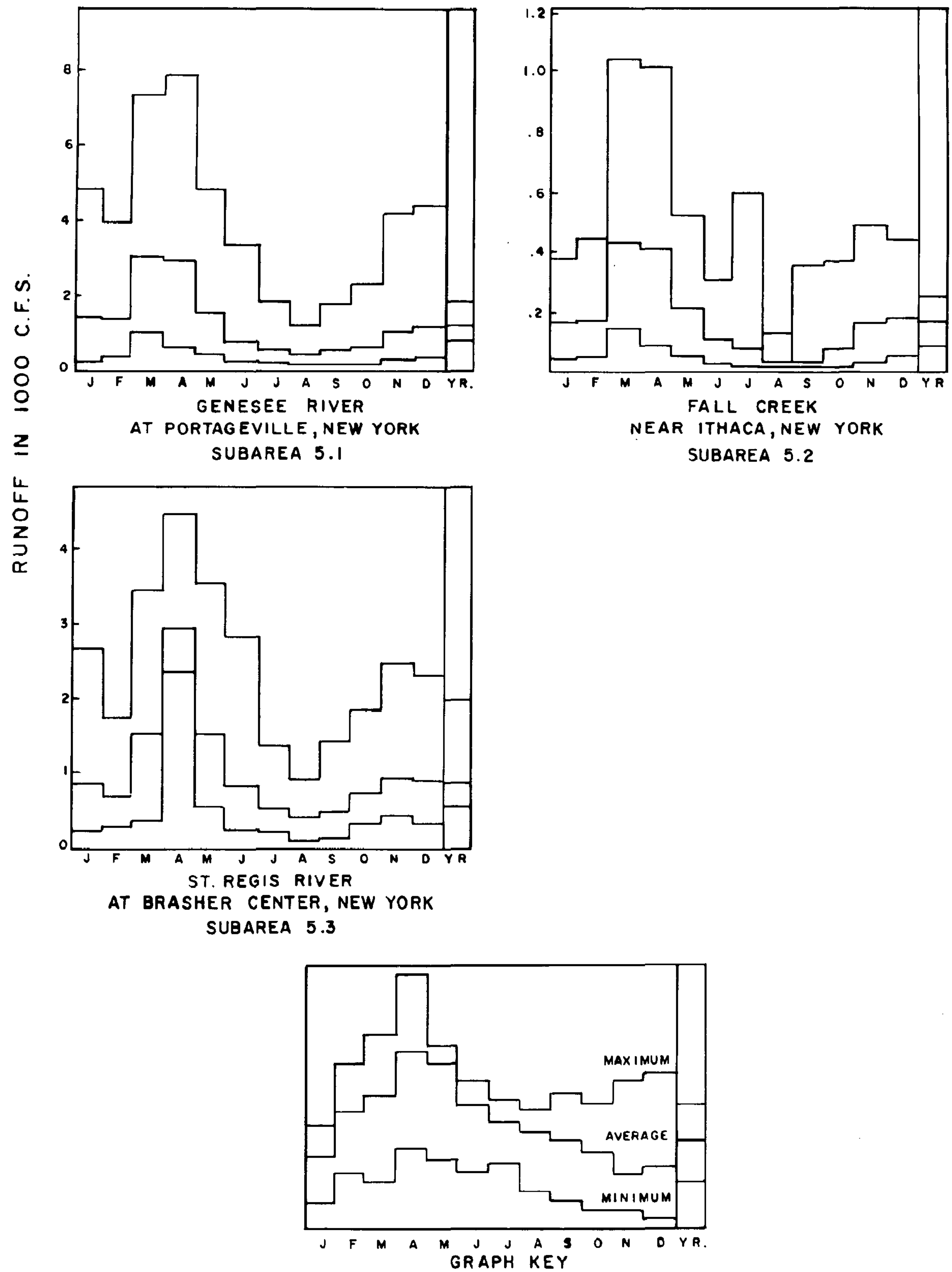


FIGURE 2–19 Monthly Distribution of Runoff, Planning Subareas 5.1, 5.2, and 5.3

TABLE 2–2 Average Monthly Distribution of Runoff

Station No. 4-	Stream and Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
						(Discharge in cfs)							
Lake Superior West-Planning Subarea 1.1													
105	Pigeon River Middle Falls, Minn.	124	106	172	1,189	1,648	903	396	233	245	303	294	167
125	Poplar River Lutsen, Minn.	37	30	43	214	330	195	84	54	62	67	80	53
145	Baptism River Beaver Bay, Minn.	27	20	63	526	514	246	80	71	93	108	124	47
170	Embarrass River Embarrass, Minn.	7	5	22	191	194	114	63	32	51	45	33	14
255	Bois Brule River Brule, Wis.	129	131	148	272	246	206	171	144	150	146	151	138
270	Bad River Odanah, Wis.	168	155	529	2,182	1,240	753	555	304	323	344	429	278
275	White River Ashland, Wis.	190	193	289	623	440	323	288	234	255	213	231	205
300	Montreal River Saxon, Wis.	161	148	283	1,016	561	417	280	211	222	190	241	178
Lake Superior East-Planning Subarea 1.2													
320	Presque Isle River near Tula, Mich.	99	89	158	956	585	307	211	142	154	171	207	142
405	Sturgeon River near Sidnaw, Mich.	65	54	132	757	490	232	130	77	110	129	158	104
425	Otter River near Elo, Mich.	111	105	195	793	382	195	126	110	111	129	162	132
430	Sturgeon River near Arnheim, Mich.	402	366	642	2,575	1,636	858	582	419	427	534	629	498
455	Tahquamenon River near Paradise, Mich.	455	438	548	2,633	1,858	614	466	318	554	748	962	786
Lake Michigan Northwest-Planning Subarea 2.1													
580	Middle Branch Escanaba River near Ishpeming, Mich.	55	44	64	456	307	139	88	64	78	102	116	81
585	East Branch Escanaba River at Gwinn, Mich.	46	39	58	347	202	103	69	48	54	73	85	64
590	Escanaba River at Cornell, Mich.	344	302	482	2,691	1,662	891	677	548	576	582	700	497
595	Ford River near Hyde, Mich.	111	79	166	1,219	930	347	182	125	208	246	302	176
610	Brule River near Florence, Wis.	235	225	287	650	525	406	369	289	304	296	318	260
645	Pine River at Pine River Powerplant near Florence, Wis.	209	188	296	929	816	548	381	309	371	364	382	249
660	Menominee River near Pembine, Wis.	1,957	1,855	2,208	5,551	5,461	3,441	2,987	2,201	2,321	2,308	2,324	2,016
665	Pike River at Amberg, Wis.	133	123	218	467	342	265	176	154	169	179	210	160
680	Peshtigo River at High Falls near Crivitz, Wis.	261	269	471	983	799	669	422	345	387	366	420	308
695	Peshtigo River at Peshtigo, Wis.	480	449	847	1,934	1,588	950	635	581	736	679	760	577
710	Oconto River near Gillett, Wis.	346	330	632	1,240	871	666	459	378	443	471	540	419
735	Fox River at Berlin, Wis.	674	734	1,746	2,190	1,395	1,129	822	747	832	915	1,007	822
755	Wolf River above West Branch, Wolf River, Wis.	390	373	540	1,030	854	678	511	433	508	522	560	432
770	Wolf River at Keshena Falls, Wis.	507	483	683	1,342	1,124	916	687	608	694	700	736	583
785	Embarrass River near Embarrass, Wis.	142	135	389	725	417	343	200	162	225	224	260	172
790	Wolf River at New London, Wis.	954	888	2,071	4,132	2,758	2,169	1,374	1,060	1,283	1,359	1,558	1,155
800	Little Wolf River at Royalton, Wis.	218	227	621	879	531	467	286	259	317	312	355	267

TABLE 2-2(continued) Average Monthly Distribution of Runoff

Station No. 4-	Stream and Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
						(Discharge in cfs)							
Lake Michigan Northwest-Planning Subarea 2.1 (continued)													
810	Waupaca River near Waupaca, Wis.	191	196	388	337	258	245	207	204	214	214	230	202
835	East Branch Fond du Lac River at Fond du Lac, Wis.	15	21	139	75	24	44	13	11	8	9	14	10
860	Sheboygan River at Sheboygan, Wis.	88	127	678	745	288	147	86	119	105	128	156	116
865	Cedar Creek near Cedarburg, Wis.	43	53	183	144	73	59	35	16	37	36	41	32
870	Milwaukee River at Milwaukee, Wis.	231	381	1,043	873	451	322	174	174	206	228	286	242
Lake Michigan Southwest-Planning Subarea 2.2													
905	Thorn Creek at Thornton, Ill.	90	111	153	177	114	89	67	40	54	56	53	66
910	Little Calumet River at South Holland, Ill.	156	208	302	294	219	137	114	62	82	92	89	110
930	Deep River at Lake George Outlet at Hobart, Ill.	96	128	190	185	133	73	58	32	39	57	55	78
940	Little Calumet River at Porter, Ind.	73	87	114	116	80	59	41	35	38	61	54	67
945	Salt Creek near McCool, Ind.	73	89	111	114	76	60	45	36	38	56	53	62
Lake Michigan Southeast-Planning Subarea 2.3													
975	St. Joseph River at Three Rivers, Mich.	879	1,024	1,666	1,762	1,382	826	575	460	443	543	668	806
985	Fawn River near White Pigeon, Mich.	133	152	213	229	194	125	98	92	87	94	114	133
1015	St. Joseph River at Niles, Mich.	3,111	3,506	4,765	5,106	4,235	3,052	2,283	1,901	1,792	2,020	2,278	2,527
1025	Paw Paw River at Riverside, Mich.	425	456	616	561	459	322	248	223	225	316	361	407
1060	Kalamazoo River at Comstock, Mich.	795	872	1,262	1,247	1,014	810	592	495	495	578	669	711
1085	Kalamazoo River near Fennville, Mich.	1,390	1,473	2,019	1,949	1,632	1,272	908	815	838	958	1,144	1,233
1130	Grand River at Lansing, Mich.	687	905	1,879	1,668	1,121	819	435	288	283	374	458	546
1190	Grand River at Grand Rapids, Mich.	3,188	3,901	7,391	6,636	4,560	3,145	1,868	1,437	1,600	1,864	2,248	2,585
Lake Michigan Northeast-Planning Subarea 2.4													
460	Black River near Garnet, Mich.	15	13	18	84	45	21	16	12	16	23	29	23
495	Manistique River at Germfast, Mich.	380	353	414	808	651	446	330	258	322	412	478	433
550	Manistique River near Blaney, Mich.	621	558	778	2,125	1,319	774	524	375	463	671	872	766
565	Manistique River near Manistique, Mich.	946	818	1,206	3,810	2,396	1,302	852	597	709	1,031	1,397	1,203
590	Escanaba River at Cornell, Mich.	344	302	482	2,691	1,662	891	677	548	576	582	700	497
1210	Muskegon River near Merritt, Mich.	188	183	255	520	371	225	161	112	114	145	184	197
1215	Muskegon River at Evart, Mich.	796	815	1,437	2,165	1,340	972	664	499	527	666	852	847
1220	Muskegon River at Newaygo, Mich.	1,791	1,933	2,886	3,315	2,429	1,870	1,357	1,150	1,214	1,431	1,762	1,765
1225	Pere Marquette River at Scottville, Mich.	616	608	829	947	734	610	475	433	461	513	607	626
1230	Big Sable River near Freesoil, Mich.	135	137	178	204	160	135	112	103	110	116	136	138
1235	Manistee River near Grayling, Mich.	172	171	182	218	193	185	176	170	175	179	185	178

TABLE 2-2(continued) Average Monthly Distribution of Runoff

Station No. 4-	Stream and Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
						(Discharge in cfs)							
	Lake Michigan Northeast-Planning Subarea 2.4 (continued)												
1240	Manistee River near Sherman, Mich.	983	979	1,155	1,490	1,156	1,033	916	856	883	936	1,017	1,007
1255	Pine River near Hoxeyville, Mich.	240	250	328	420	306	264	231	236	235	254	277	267
1260	Manistee River near Manistee, Mich.	1,836	1,841	2,191	2,953	2,197	1,897	1,694	1,591	1,641	1,782	1,933	1,946
1270	Boardman River near Mayfield, Mich.	167	166	197	286	223	193	174	159	168	174	186	185
	Lake Huron North-Planning Subarea 3.1												
1300	Cheboygan River near Cheboygan, Mich.	812	800	860	1,072	1,047	815	649	551	597	616	718	770
1325	Thunder Bay River near Hillman, Mich.	185	178	241	372	260	201	170	152	165	177	202	196
1365	Au Sable River at Mio, Mich.	819	806	957	1,410	1,129	950	827	772	800	850	904	887
1385	Au Gres River near National City, Mich.	58	73	205	280	145	70	35	27	31	52	68	81
1420	Rifle River near Sterling, Mich.	244	280	550	627	387	281	183	165	176	212	259	265
	Lake Huron Central-Planning Area 3.2												
1440	Shiawassee River at Byron, Mich.	234	316	540	485	346	173	115	82	78	124	161	210
1445	Shiawassee River at Owosso, Mich.	296	413	697	645	461	244	127	93	102	133	184	238
1450	Shiawassee River near Fergus, Mich.	388	519	985	843	624	323	178	116	126	175	238	310
1460	Farmers Creek near Lapeer, Mich.	25	37	71	64	42	23	9	8	9	11	16	21
1485	Flint River near Flint, Mich.	470	687	1,392	1,208	750	420	199	180	193	212	289	378
1500	S. Br. Cass River near Cass City, Mich.	100	162	438	308	131	57	44	21	10	15	37	85
1505	Cass River at Cass City, Mich.	174	255	720	500	218	82	61	30	15	24	70	132
1510	Cass River at Vassar, Mich.	333	494	1,199	967	469	194	139	85	59	76	173	277
1515	Cass River at Frankenmuth, Mich.	393	549	1,515	1,071	630	334	153	92	80	121	216	306
1525	Tobacco River at Beaverton, Mich.	290	344	672	746	423	284	260	198	212	255	300	316
1535	Salt River near N. Bradley, Mich.	53	99	274	178	87	52	31	13	17	26	40	49
1540	Chippewa River near Mt. Pleasant	260	321	565	564	354	250	175	147	166	197	248	257
1545	Chippewa River near Midland, Mich.	325	412	877	997	557	318	258	185	188	234	326	361
1550	Pine River at Alma, Mich.	176	221	437	403	257	158	94	80	96	121	166	172
1555	Pine River near Midland, Mich.	234	334	589	620	333	193	137	113	127	151	200	234
1560	Tittabawassee River at Midland, Mich.	1,147	1,534	3,612	3,496	1,983	1,205	660	460	546	748	1,087	1,132
1585	Pigeon River near Owendale, Mich.	16	30	103	63	35	17	8	5	4	8	13	23
	Lake Erie Northwest-Planning Subarea 4.1												
1595	Black River near Fargo, Mich.	244	395	993	646	325	170	70	61	27	66	82	181
1645	N. Br. Clinton River near Mount Clemens, Mich.	111	180	322	260	140	45	21	13	15	30	54	106
1655	Clinton River at Mount Clemens, Mich.	458	686	1,050	1,000	689	404	218	161	157	197	252	385
1660	River Rouge at Birmingham, Mich.	12	17	33	30	20	10	6	4	3	6	9	13

TABLE 2–2(continued) Average Monthly Distribution of Runoff

Station No. 4-	Stream and Station	Jan	Feb	Mar	Apr	May	Jun (Discharge in cfs)	Jul	Aug	Sept	Oct	Nov	Dec
Lake Erie Northwest-Planning Subarea 4.1 (continued)													
1665	River Rouge at Detroit, Mich.	105	160	223	230	168	80	40	32	26	41	57	88
1670	Middle River Rouge near Garden City, Mich.	70	92	137	128	89	42	28	22	20	28	37	58
1680	Lower River Rouge at Inkster, Mich.	56	87	126	108	49	22	12	9	8	14	23	46
1695	Huron River at Commerce, Mich.	36	39	60	71	53	31	20	15	18	20	26	33
1700	Huron River at Milford, Mich.	92	103	147	161	115	75	56	45	51	62	75	88
1705	Huron River near New Hudson, Mich.	109	120	157	141	122	86	61	54	61	76	122	115
1715	Ore Creek near Brighton, Mich.	20	22	39	41	30	19	13	10	9	15	18	20
1720	Huron River near Hamburg, Mich.	181	193	315	296	257	162	119	99	95	126	187	180
1730	Huron River near Dexter, Mich.	341	376	606	688	501	297	180	137	163	198	282	323
1735	Mill Creek near Dexter, Mich.	52	73	155	135	79	47	26	21	20	35	46	63
1745	Huron River at Ann Arbor, Mich.	469	549	841	853	592	337	220	162	179	249	355	421
1765	River Raisin near Monroe, Mich.	730	963	1,600	1,391	960	482	276	149	143	225	376	504
Lake Erie Southwest-Planning Subarea 4.2													
1805	St. Joseph River near Fort Wayne, Ind.	1,475	1,584	2,103	1,986	1,508	640	447	253	194	354	436	657
1820	St. Mary's River near Fort Wayne, Ind.	933	951	1,329	1,163	701	423	252	141	73	138	220	466
1835	Maumee River at Antwerp, Ohio	2,327	2,432	3,619	3,339	2,225	1,123	694	418	405	528	869	1,565
1960	Sandusky River near Bucyrus, Ohio	148	144	175	125	79	61	34	14	14	28	51	92
1965	Sandusky River near Upper Sandusky, Ohio	412	433	562	427	239	169	89	42	42	53	112	231
1970	Sandusky River near Mexico, Ohio	974	1,010	1,376	1,016	533	414	208	104	111	118	237	519
1980	Sandusky River near Fremont, Ohio	1,601	1,703	2,270	1,714	938	669	317	161	172	186	366	828
1990	Huron River at Milan, Ohio	402	498	719	573	296	150	107	61	23	32	129	232
1995	Vermilion River near Vermilion, Ohio	325	418	620	482	239	81	67	41	11	14	82	196
Lake Erie Central-Planning Subarea 4.3													
2005	Black River at Elyria, Ohio	492	557	799	645	346	200	69	61	32	31	100	231
2015	Rocky River near Berea, Ohio	398	456	580	504	249	122	63	54	48	78	129	235
2060	Cuyahoga River at Old Portage, Ohio	561	617	877	733	466	273	200	158	157	183	250	373
2080	Cuyahoga River at Independence, Ohio	1,098	1,172	1,620	1,427	880	506	331	260	191	264	415	678
2090	Chagrin River at Willoughby, Ohio	473	514	691	562	338	194	96	86	78	141	233	337
2115	Mill Cr. near Jefferson, Ohio	175	206	259	177	113	43	18	22	17	33	77	139
2120	Grand River near Madison, Ohio	1,096	1,251	1,618	1,162	665	252	126	113	144	217	385	754
2125	Ashtabula River near Ashtabula, Ohio	234	256	332	245	148	56	20	23	30	68	121	223
2130	Conneaut Cr. at Conneaut, Ohio	424	412	518	381	229	71	38	47	69	104	215	382

TABLE 2-2(continued) Average Monthly Distribution of Runoff

Station No. 4-	Stream and Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
						(Discharge in cfs)							
Lake Erie East-Planning Subarea 4.4													
2135	Cattaraugus Cr. at Gowanda, N.Y.	839	895	1,684	1,502	748	431	232	180	222	281	515	840
2145	Buffalo Cr. at Gardenville, N.Y.	234	282	509	403	170	81	33	29	37	58	130	229
2150	Cayuga Cr. near Lancaster, N.Y.	157	203	351	268	104	39	14	16	20	36	86	152
2155	Cazenovia Cr. at Ebenezer, N.Y.	290	325	572	437	197	86	32	31	42	75	176	293
2165	Little Tonawanda Cr. at Linden, N.Y.	36	40	84	66	28	13	4	3	3	7	13	25
2170	Tonawanda Cr. at Batavia, N.Y.	238	290	569	474	195	75	38	29	31	52	89	189
Lake Ontario West-Planning Subarea 5.1													
2215	Genesee R. at Scio, N.Y.	398	402	931	898	525	253	158	98	99	148	303	349
2230	Genesee River at Portageville, N.Y.	1,407	1,366	3,006	2,837	1,532	758	404	290	330	501	910	1,130
2250	Canaseraga Cr. near Dansville, N.Y.	146	166	388	364	200	111	66	40	42	55	94	123
2275	Genesee River at Jones Bridge	1,857	1,759	4,101	3,655	2,127	1,058	563	375	383	698	1,206	1,436
2305	Oatka Cr. at Garbutt, N.Y.	189	257	558	521	237	106	55	39	33	51	62	138
2310	Black Cr. at Churchville, N.Y.	99	164	330	252	116	45	19	11	10	25	34	70
2320	Genesee River at Driving Park, N.Y.	2,641	3,078	6,191	6,132	3,572	1,962	1,191	966	940	1,222	1,883	2,450
Lake Ontario Central-Planning Subarea 5.2													
2330	Cayuga Inlet near Ithaca, N.Y.	34	44	97	85	52	25	12	97	9	18	25	34
2340	Fall Cr. near Ithaca, N.Y.	186	195	440	413	214	114	70	48	54	84	150	182
2425	East Br. Fish Cr. at Taberg, N.Y.	490	396	828	1,673	674	256	169	135	209	364	576	555
2435	Oneida Cr. at Oneida, N.Y.	180	199	364	324	149	76	55	47	39	49	97	149
2440	Chittenango Cr. near Chittenango, N.Y.	122	144	235	252	111	63	41	37	32	38	79	116
2450	Limestone Cr. at Fayetteville, N.Y.	152	176	324	267	150	90	52	44	45	58	91	138
Lake Ontario East-Planning Subarea 5.3													
2525	Black River near Boonville, N.Y.	627	531	972	1,880	934	455	320	239	300	441	645	671
2560	Independence River at Donnattsburg, N.Y.	155	144	270	529	247	118	81	57	79	123	192	177
2625	West Br. Oswegatchie River near Harrisville, N.Y.	481	399	838	1,364	666	330	206	149	176	338	509	521
2650	Grass River at Pyrites, N.Y.	521	458	920	1,627	836	424	268	222	250	399	563	545
2690	St. Regis River at Brasher Center, N.Y.	860	707	1,494	2,881	1,544	831	520	418	464	692	919	894

Section 3

FLOOD CHARACTERISTICS

3.1 General

Because available streamflow records on most of the tributaries to the Great Lakes cover relatively short periods, a reliable picture of flood potential cannot always be obtained from an examination of streamflow records alone. Therefore, any investigation of flooding should include a thorough search of historical records contained in newspaper files, public libraries, historical society libraries, and other sources. Because the flood data contained in this section are derived entirely from streamflow records, they may be somewhat misleading. Flooding by rivers in the Basin is most often caused by high-intensity rainstorms or by a combination of snowmelt and rainfall on partially frozen ground. Although flooding can be experienced in almost any month of the year, it is most common in late winter or early spring and is generally associated with snowmelt. Flood stages are frequently increased by ice jams, especially at the mouth of a river, where its capacity can be restricted by either sheet ice or windblown ice from the lake. The magnitude and number of flood occurrences in the Great Lakes Basin are discussed in detail in U.S. Geological Survey Water Supply Paper 1677.[8] Appendix 14, *Flood Plains*, discusses existing and projected flood damage potential within the Basin in depth.

3.2 Annual Peak Flood Frequencies

Floods are random occurrences dependent on a combination of natural climatological factors and channel conditions, and there is no method of accurately predicting the time of occurrence or magnitude of any future flood event. However, an analysis of past flood events can give an indication of probability of occurrence of a given stage or discharge. In connection with flood damages and flood-control planning, it is customary to estimate the frequency (or probability) with which specific flood stages or discharges may be equaled or exceeded rather than the frequency of an exact value of stage or discharge. Such estimates are properly designated as exceedence frequency but in practice are usually referred to simply as frequency. Frequency is usually expressed in units of percent, such as the 2-percent flood peak, which means the flood peak that would have a 2-percent chance of being equaled or exceeded in any one year.

The annual peak frequency data developed for this appendix were based on the log Pearson Type III statistical procedure with zero skew coefficient. Extremely high or low discharge events, considered atypical of the period of record, were adjusted prior to use in the computations. The expected probability adjustment was not applied to the computed percentage values. The Water Resources Council, Bulletin 15, recommends that the log Pearson Type III procedure be used as a uniform technique for determining flood-flow frequencies. A regionalized study of several shorter-term stations would lead to a regionalized skew coefficient with sufficient reliability to use in the place of zero skew. However, a regionalized study of skew coefficients has not been made and is beyond the scope of this report.

Table 2–3 includes, for selected hydrologic stations in each planning subarea, the maximum instantaneous recorded flow with its frequency in percent; the discharge magnitude for the 2-year, 50-year, and 100-year floods; the maximum gage height of record; and the mean sea level elevation of zero on the gage. Frequency curves for all studies listed in Table 2–3 can be reconstructed by plotting the 2-, 50-, and 100-year values shown and drawing a straight line through the points.

Figures 2–20 through 2–34 are annual peak discharge-frequency curves developed for selected hydrologic stations considered typical of each planning subarea. Curves and statistical data developed for the other hydrologic stations are available in the office of the Great Lakes Basin Commission. Where possible, the selected hydrologic stations represent runoff conditions free from artificial control or regulation. Each figure shows a relationship that can be used to transfer the discharge-frequency data from the station with a given drainage area to a second location having the same hydrologic regimen and a like-numbered hydrologic area, but with a different drainage area. The new frequency curve would be established by multiplying the known discharge values from the given frequency curve for selected frequencies by the factor interpolated from the table. Caution must be used, however, when extrapolating values for drainage areas smaller or larger than the areas shown in the table. The degree of accuracy becomes questionable beyond these limits. The factors shown in the relationship were developed from data shown in Figures 2, 3, and 4 of U.S. Geological Survey Water Supply Paper 1677.[9] These data can be generally used to determine peak discharge-frequency curves for ungaged areas. It must be stressed that curves derived in this manner should be used for preliminary planning purposes only and that design of specific projects must be based on a detailed study of the specific area. Some areas within the Basin have already been studied in greater detail than required for this report. Frequency data developed in these studies would be exceptions to the generalized curves developed for this appendix. Basins in which these more advanced studies have been conducted are listed in Subsection 3.6.

3.3 Partial Duration Flood Frequencies

Nearly every steam has more than one peak during any given year. Secondary peaks for some years may be substantially higher than the maximum peaks of other years. Therefore, a curve based on all peaks, instead of just the annual maximums, would be less sloped at the lower end because many of the smaller annual maximum peaks would have been eliminated from consideration. A curve based on all peaks above a certain base, regardless of the number of peaks occurring in a year, is a partial duration curve. Frequency curves developed in this manner provide a more realistic evaluation of flood damages in cases where damage potential remains high regardless of the number of flood occurrences within a given year.

In the event that secondary peak data are not available or that only preliminary information is needed, the empirical relationship between partial duration and annual peaks curves, developed by Walter Langbein, can be used. Langbein's relationship was first presented in 1949.[1]

3.4 Alternative Frequency Methodologies

The basic frequency data for this appendix were developed in accordance with the method in papers by Leo R. Beard.[2] This procedure is based upon the log Pearson Type III distribution. Although this procedure is standard with the U.S. Army Corps of Engineers, it offers a somewhat different approach for determining frequencies than those used by other agencies. The resulting differences can be significant when considering localized cases, but using one procedure instead of another would have little impact on framework-scope study results. Methodologies of other agencies are summarized in the following paragraphs to indicate potential differences from the base approach used in this report.

The U.S. Geological Survey and the Soil Conservation Service also use the log Pearson Type III distribution for computing frequency curves when stream records are available. This method is described in the Water Resources Council Bulletin 15.[10] These agencies generally utilize a skew coefficient developed from the recorded data of the hydrologic station being studied. The resulting curve, when compared with a frequency curve developed by Beard's method, usually differs in the upper extremes, or the area representing less frequent flood events. Differences can also occur because of normal Corps of Engineers practice to adjust extreme high or low discharge events to be more in line with other observed data. The Corps of Engineers method also places less reliance on data obtained from stations having short periods of record, and often correlates the shorter periods of record with data obtained from other stations in the area.

Methods used by the Soil Conservation Service to estimate the frequency of events such as flood peaks are found in that agency's *National Engineering Handbook (NEH) 4, Hydrology*.[9] Frequency analyses of peak discharge and runoff volume data are also accomplished by means of a computer program prepared by the Central Technical Unit of the Soil Conservation Service, Washington, D.C. This program utilizes primarily the two-parameter gamma distribution for computing the 0- to 99-

percent chance events and the log-normal distribution whenever the gamma statistic is greater than 51.

The Soil Conservation Service when analyzing runoff from small ungaged watersheds determines discharge frequency based on observed rainfall-runoff data. Rainfall-frequency relationships for different durations are obtained from data in Technical Paper No. 40,[8] prepared for the Soil Conservation Service by the Weather Bureau, now the National Weather Service. Frequency curves developed by these methods generally result in curves with a flatter slope than curves developed by the base method using zero skew.

3.5 Flood Volumes

A knowledge of flood volume is necessary when determining the effectiveness of sizes of storage reservoirs needed to control flooding. Relationships between flood volume, duration, and frequency can be developed using procedures similar to those described for flood peak frequency in this chapter of the appendix. Flood volume-duration-frequency data were not developed for this appendix. However, basic data needed for these studies are available in the statistical summary papers computed by the District offices of the U.S. Geological Survey for streamflow stations included in their reporting network. A rough estimate of expected flood volumes based on peak monthly flows for the selected hydrologic stations in each planning subarea can be obtained from the maximum monthly discharge data contained in Table 2–1 or Figures 2–16 through 2–19. Monthly runoff in acre-feet is computed by multiplying monthly average discharge in cubic feet per second by 60.

3.6 Exceptions and Special Cases

Hydrological studies for several river basins have been completed with greater accuracy than evaluations in this appendix. Where these data are available, they should be used in preference to data in this appendix. These river basins include the Bad River, Wisconsin, in Planning Subarea 1.1; Sturgeon River, Michigan, in Planning Subarea 1.2; Kalamazoo and Grand Rivers, Michigan, in Planning Subarea 2.3; Little Calumet River, Indiana, in Planning Subarea 2.2; Saginaw River, Michigan, in Planning Subarea 3.2; River Rouge, Michigan, in Planning Subarea 4.1; Genesee River basin in Planning Subarea 5.1; Oswego River basin in Planning Subarea 5.2; and others. Further information on these completed studies is contained in the Bibliography of this appendix.

Rivers in the Basin known to be controlled and regulated by storage reservoirs and also augmented by flows from mining operations should be analyzed as special cases and not by using the generalized data of this appendix. These rivers include the St. Louis River in PSA 1.1; the Montreal River in PSAs 1.1 and 1.2; the Ontonagon River in PSA 1.2; the Menominee River in PSA 2.1; the Thunder Bay River in PSA 3.1; the Flint and Tittabawassee Rivers in PSA 3.2; and the Black River in PSA 5.3.

TABLE 2–3 Flood Characteristics of Streams

Station No. 4-	Stream and Station	Instantaneous Flows of Record (cfs)	(% prob)	Discharge Frequency 2-year (cfs)	50-year (cfs)	100-year (cfs)	Gage Height of Record (ft)	1929 Datum Gage Zero (ft)
Lake Superior West--Planning Subarea 1.1								
105	Pigeon River Middle Falls, Minn.	11,000	3.4	4,550	12,330	14,000	7.6	789.58[a]
125	Poplar River Lutsen, Minn.	1,880	2.8	820	2,000	2,250	6.23	697.89
145	Baptism River Beaver Bay, Minn.	9,350	1	2,400	7,900	9,350	8.11[b]	609.97
170	Embarrass River Embarrass, Minn.	1,740	5	610	2,250	2,650	10.92	1410.36
255	Bois Brule River Brule, Wis.	1,520	4	680	1,750	1,975	5.2	948.49
270	Bad River Odanah, Wis.	27,700	0.6	8,200	22,000	25,000	21.7	668.3
275	White River Ashland, Wis.	6,270	5	2,700	7,800	9,000	7.90	660.15
300	Montreal River Saxon, Wis.	6,600	4	3,500	7,400	8,200	7.50	760
Lake Superior East--Planning Subarea 1.2								
320	Presque Isle River Near Tula, Mich.	4,640	4.9	2,420	5,400	6,000	14.04	1299.66
405	Sturgeon River Near Sidnaw, Mich.	4,630	3.7	2,290	5,150	5,725	11.63	1214.40[a]
425	Otter River Near Elo, Mich.	4,540	10.0	2,710	6,175	6,880	13.52	630.0[a]
430	Sturgeon River Near Arnheim, Mich.	15,500	1.95	6,000	14,900	16,850	14.57	605.98
455	Tahquamenon River Near Paradise, Mich.	6,990	3.4	4,200	7,400	8,000	10.26	697.0
Lake Michigan Northwest--Planning Subarea 2.1								
590	Escanaba River at Cornell, Mich.	10,500	5	6,050	12,200	13,250	4.90	749.26[a]
610	Brule River Near Florence, Wis.	4,700	0.6	1,530	3,800	4,300	6.57	1210.0
645	Pine River at Pine River Power Plant Near Florence, Wis.	4,380	1.2	1,900	4,075	4,500	-	-
660	Menominee River Near Pembine, Wis.	26,900	6.5	13,400	34,100	38,500	13.90	745.0
665	Pike River at Amberg, Wis.	2,800	0.4	1,100	2,200	2,450	7.8	865[a]
680	Peshtigo River at High Falls Near Crivitz, Wis.	3,670	2.8	2,000	3,800	4,150	-	810.0[a]
695	Peshtigo River at Peshtigo, Wis.	9,790	0.95	4,300	8,700	9,550	11.59	584.64
710	Oconto River at Gillett, Wis.	8,400	0.4	2,500	6,400	7,200	11.2	735.0[a]
735	Fox River at Berlin, Wis.	6,900	4	3,425	7,800	8,750	15.5	744.52[a]
755	Wolf River Above West Branch Wolf River, Wis.	3,120	0.5	1,760	2,790	2,940	6.60	856.57
770	Wolf River at Keshena Falls, Wis.	4,830	0.75	2,400	4,325	4,700	9.67	820.0[a]
785	Embarrass River Near Embarrass, Wis.	7,080	1.39	2,270	6,550	7,550	12.13	800.0[a]
790	Wolf River at New London, Wis.	15,500	2.0	6,200	15,500	17,900	11.4	749.37
800	Little Wolf River at Royalton, Wis.	6,950	6.1	3,090	9,600	11,200	8.0	774.0[a]
810	Waupaca River Near Waupaca, Wis.	2,520	4.0	1,050	2,990	3,400	6.90	780.0[a]

TABLE 2–3(continued) Flood Characteristics of Streams

Station No. 4-	Stream and Station	Instantaneous Flows of Record (cfs)	(% prob)	Discharge Frequency 2-year (cfs)	50-year (cfs)	100-year (cfs)	Gage Height of Record (ft)	1929 Datum Gage Zero (ft)
Lake Michigan Northwest--Planning Subarea 2.1 (continued)								
835	East Branch Fond du Lac River at Fond du Lac, Wis.	2,140	10.5	790	4,200	5,210	5.87	762.82
860	Sheboygan River at Sheboygan, Wis.	7,140	11.3	2,890	13,300	16,500	9.40	584.00[a]
865	Cedar Creek Near Cedarburg, Wis.	3,600	6.0	960	5,500	6,975	12.25	795.33
Lake Michigan Southwest--Planning Subarea 2.2								
905	Thorn Creek at Thornton, Ill.	4,700	4.8	1,925	5,800	6,750	16.0	586.43
910	Little Calumet River at South Holland, Ill.	4,440	7.1	2,350	5,700	6,450	20.11	575.00
930	Deep River at Lake George Outlet at Hobart, Ind.	3,880	2.7	1,300	4,190	4,875	19.48	588.17[a]
940	Little Calumet River at Porter, Ind.	3,110	3.3	1,035	3,540	4,175	11.66	603.48
945	Salt Creek at McCool, Ind.	3,180	1.6	880	3,000	3,525	14.12	594.10
Lake Michigan Southeast--Planning Subarea 2.3								
975	St. Joseph River at Three Rivers, Mich.	4,200	15	3,050	5,700	6,200	7.78	781.34
990	St. Joseph River at Mottville, Mich.	10,700	0.6	4,650	9,300	10,200	6.56	755.50
995	Pigeon Creek at Hogback L. Near Angola, Ind.	744	3.5	320	830	940	14.95	940.00
1002.2	N. Br. Elkhart River Near Cosperville, Mich.	717	11	410	1,025	1,150	8.78	880
1005	Elkhart River at Goshen, Ind.	5,440	6.3	2,520	7,100	8,200	10.15	769.43
1010	St. Joseph River at Elkhart, Ind.	18,400	1.6	8,800	17,800	19,700	27.82	700
1015	St. Joseph River at Niles, Mich.	20,200	1.8	9,400	20,000	22,200	13.10	635.02
1025	Paw Paw River at Riverside, Mich.	1,650	7	1,150	1,900	2,020	8.98	588.80
1035	Kalamazoo River at Marshall, Mich.	2,130	1.7	930	2,100	2,320	8.20	877.09
1050	Battle Creek at Battle Creek, Mich.	3,640	1.9	1,190	3,600	4,150	4.48	823.24
1055	Kalamazoo River Near Battle Creek, Mich.	7,290	0.7	2,400	6,000	6,900	9.13	815
1060	Kalamazoo River at Comstock, Mich.	6,910	1.10	2,700	6,300	7,000	7.94	759.12
1085	Kalamazoo River Near Fennville, Mich.	17,500	6.5	14,300	19,100	20,000	606.76	586.51
1090	Grand River at Jackson, Mich.	1,070	1.9	620	1,060	1,140	13.50	900.00
1110	Grand River Near Eaton Rapids, Mich.	3,360	12	1,900	5,100	5,800	7.65	852.68
1125	Red Cedar River at East Lansing, Mich.	5,920	3.8	1,960	6,900	8,200	11.58	824.39
1130	Grand River at Lansing, Mich.	24,500	0.3	5,200	16,500	19,000	18.60	805.53

TABLE 2–3(continued) Flood Characteristics of Streams

Station No. 4-	Stream and Station	Instantaneous Flows of Record (cfs)	Instantaneous Flows of Record (% prob)	Discharge Frequency 2-year (cfs)	Discharge Frequency 50-year (cfs)	Discharge Frequency 100-year (cfs)	Gage Height of Record (ft)	1929 Datum Gage Zero (ft)
Lake Michigan Southeast--Planning Subarea 2.3 (continued)								
1140	Grand River at Portland, Mich.	9,100	5.5	4,400	11,200	12,700	11.56	705.00
1145	Looking Glass River Near Eagle, Mich.	2,860	4.9	1,030	3,600	4,250	7.70	747.09
1150	Maple River at Maple Rapids, Mich.	6,500	5.3	1,890	9,000	11,200	11.22	642.58
1160	Grand River at Ionia, Mich.	21,500	7	9,500	29,500	4,500	23.43	615.38
1165	Flat River at Smyrna, Mich.	3,100	11	1,500	3,100	3,450	7.27	729.53
1175	Thornapple River Near Hastings, Mich.	6,810	2.25	1,980	7,000	8,100	10.20	786.71
1180	Thornapple River Near Caledonia, Mich.	6,290	4.70	2,550	8,000	9,400	10.79	676.31
1185	Rogue River Near Rockford, Mich.	2,640	3	1,280	2,830	3,150	8.59	625.2
1190	Grand River at Grand Rapids, Mich.	54,000	1.6	17,500	52,000	60,000	19.5	585.70
Lake Michigan Northeast--Planning Subarea 2.4								
460	Black River Near Garnet, Mich.	860	0.7	250	700	800	8.55	629.7
550	Manistique River Near Blaney, Mich.	9,300	0.6	3,500	7,800	8,650	19.42	612.55
565	Manistique River Near Manistique, Mich.	16,900	1	6,250	15,000	16,800	12.85	608
590	Escanaba River at Cornell, Mich.	8,340	18	6,100	12,200	13,300	4.52	749.26
1210	Muskegon River Near Merritt, Mich.	1,340	4	765	1,450	1,600	8.16	1,117.82
1215	Muskegon River at Evart, Mich.	7,750	4	4,100	6,800	9,500	14.42	977.72
1220	Muskegon River at Newago, Mich.	14,950	0.4	5,850	12,000	13,200	5.31	625.83
1225	Pere Marquette River Scottsville, Mich.	2,740	6	1,620	3,300	3,650	5.84	597.66
1230	Big Sable River Near Freesoil, Mich.	555	5	340	640	685	3.4	615.32
1235	Manistee River Near Grayling, Mich.	388	2	295	390	405	1.88	1,120.64
1240	Manistee River Near Sherman, Mich.	3,570	1	2,330	3,430	3,600	7.1	804
1255	Pine River Near Hoxeyville, Mich.	2,440	0.8	1,000	2,100	2,350	6.82	775
1260	Manistee River Near Manistee, Mich.	6,800	11	4,900	8,400	9,000	8.16	585
1270	Boardman River Near Mayfield, Mich.	1,220	2	640	1,230	1,350	6.90	760
Lake Huron North--Planning Subarea 3.1								
1280	Sturgeon River Near Wolverine, Mich.	1,180	2.5	650	1,230	1,340	4.48	740
1285	Indian River at Indian River, Mich.	1,140	4	840	1,200	1,250	5.58	590.21
1290	Pigeon River Near Vanderbilt, Mich.	1,500	1.8	450	1,480	1,710	6.80	886.24

TABLE 2-3(continued) Flood Characteristics of Streams

Station No. 4-	Stream and Station	Instantaneous Flows of Record (cfs)	(% prob)	Discharge Frequency 2-year (cfs)	50-year (cfs)	100-year (cfs)	Gage Height of Record (ft)	1929 Datum Gage Zero (ft)
Lake Huron North--Planning Subarea 3.1 (continued)								
1295	Pigeon River at Afton, Mich.	1,170	4	645	1,310	1,450	6.80	675
1300	Cheboygan River Near Cheboygan, Mich.	1,640	7	1,350	1,780	1,840	3.27	591.21
1305	Black River Near Tower, Mich.	2,340	2	1,130	2,250	2,450	7.13	658.00
1315	Rainy River Near Ocqueoc, Mich.	946	5.5	730	1,120	1,450	6.33	674.85
1320	Black River Near Cheboygan, Mich.	2,500	4	1,430	2,700	2,925	5.74	609.26
1325	Thunder Bay River Near Hillman, Mich.	1,380	10	830	1,880	2,080	8.86	760
1335	Thunder Bay River Near Bolton, Mich.	4,070	5	2,100	5,650	6,450	9.99	671.96
1355	Au Sable River at Grayling, Mich.	274	2.5	162	278	298	3.00	1,123.49
1365	Au Gres River at McIvor, Mich.	1,310	5.5	495	1,550	1,840	8.88	646.58
1385	Au Gres River Near National City, Mich.	1,970	18.5	1,040	4,500	5,450	7.87	710
1390	Houghton Creek Near Lupton, Mich.	955	2.5	335	1,000	1,150	7.15	864.55
1395	Rifle River "At the Ranch" Near Lupton, Mich.	1,330	1.6	495	1,280	1,460	10.10	857.47
1400	Prior Creek Near Selkirk, Mich.	584	1.5	192	545	625	5.64	840
1405	Rifle River at Selkirk, Mich.	2,760	2	920	2,750	3,200	6.67	828.47
1420	Rifle River Near Sterling, Mich.	5,340	3.5	2,220	5,800	6,600	13.74	649.48
Lake Huron Central--Planning Subarea 3.2								
1435	N. Br. Kawkawlin River Near Kawkawlin, Mich.	1,540	11	700	2,650	3,150	10.33	584.00
1440	Shiawassee River at Byron, Mich.	2,900	9	1,400	4,350	5,000	12.58	811.54
1445	Shiawassee River at Owosso, Mich.	6,240	5	2,250	8,100	9,600	10.35	707.25
1450	Shiawassee River Near Fergus, Mich.	7,500	7	3,450	10,000	11,500	13.44	587.80
1460	Farmers Creek Near Lapeer, Mich.	1,280	2.2	305	1,325	1,600	19.87	805.79
1475	Flint River Near Otisville, Mich.	6,150	6	1,800	8,850	10,000	14.97	721.39
1485	Flint River Near Flint, Mich.	14,900	1.2	4,600	13,400	15,250	16.35	678.80
1490	Flint River Near Fosters, Mich.	19,000	1.6	5,800	18,250	21,000	18.5	582.22
1500	S. Br. Cass River Near Cass City, Mich.	-	-	2,150	-	-	-	719.5
1505	Cass River at Cass City, Mich.	8,460	11	3,050	16,250	20,000	15.80	697.92
1510	Cass River at Vassar, Mich.	11,400	16	5,100	26,500	33,000	16.70	612.38
1515	Cass River at Frankenmuth, Mich.	17,700	18	6,450	29,500	35,500	20.88	583.96
1525	Tobacco River at Beaverton, Mich.	7,680	5	3,680	8,600	10,500	12.95	683.27

TABLE 2–3(continued) Flood Characteristics of Streams

Station No. 4-	Stream and Station	Instantaneous Flows of Record (cfs)	Instantaneous Flows of Record (% prob)	Discharge Frequency 2-year (cfs)	Discharge Frequency 50-year (cfs)	Discharge Frequency 100-year (cfs)	Gage Height of Record (ft)	1929 Datum Gage Zero (ft)
Lake Huron Central--Planning Subarea 3.2 (continued)								
1535	Salt River Near Bradley, Mich.	8,200	4	2,000	-	-	14.95	616.01
1540	Chippewa River Near Mt. Pleasant, Mich.	4,960	3	1,825	5,250	6,100	12.78	710.38
1545	Chippewa River Near Midland, Mich.	8,510	3	2,950	9,000	-	9.85	612.35
1550	Pine River at Alma, Mich.	4,400	3	1,380	5,100	6,100	10.81	718.37
1555	Pine River Near Midland, Mich.	6,360	4	2,200	7,420	8,650	10.00	623.94
1560	Tittabawassee River at Midland, Mich.	34,000	6	12,500	41,000	54,500	19.50	580.28
1585	Pigeon River Near Owendale, Mich.	2,550	12	725	6,400	8,400	10.75	645
Lake Erie Northwest--Planning Subarea 4.1								
1595	Black River Near Fargo, Mich.	14,400	9	5,000	24,500	30,500	16.06	613.75
1640	Clinton River Near Fraser, Mich.	8,000	5	3,400	9,900	11,250	19.5	577.71
1645	N. Br. Clinton River Near Mt.Clemens, Mich.	5,830	6	2,250	8,200	9,650	16.87	576.38
1655	Clinton River at Mt. Clemens, Mich.	21,200	2	5,250	22,400	26,500	12.15	570.43
1660	River Rouge at Birmingham, Mich.	700	6	275	925	1,100	5.60	715.94
1665	River Rouge at Detroit, Mich.	13,000	0.7	1,900	9,450	11,400	23.0	584.00
1670	M. River Rouge Near Garden City, Mich.	2,150	6	1,050	2,650	3,000	10.50	600.95
1680	L. River Rouge at Inkster, Mich.	3,120	6	1,425	4,100	4,700	12.42	593.14
1690	Huron River at Commerce, Mich.	266	2	110	260	290	2.98	910.00
1700	Huron River at Milford, Mich.	645	2	310	665	740	8.25	880.00
1705	Huron River Near New Hudson, Mich.	1,080	0.6	340	860	965	5.05	868.00
1715	Oregon Creek Near Brighton, Mich.	193	0.7	785	168	185	16.50	850.56
1720	Huron River Near Hamburg, Mich.	1,560	1	585	1,400	1,580	8.35	850.00
1725	Portage River Near Pinckney, Mich.	529	1	175	490	560	5.72	860.38
1730	Huron River Near Dexter, Mich.	3,120	1	1,075	2,900	3,350	8.17	837.11
1735	Mill Creek Near Dexter, Mich.	1,300	7	700	1,650	1,850	12.2	850.00
1745	Huron River at Ann Arbor, Mich.	5,840	1.2	1,900	5,300	6,010	10.66	744.81
1765	River Raisin Near Monroe, Mich.	12,900	5	5,400	16,250	18,500	10.7	616.26
Lake Erie Southwest--Planning Subarea 4.2								
1780	St. Joseph River Near Newville, Ind.	9,710	3	4,000	10,600	12,200	17.05	795.40
1795	Cedar Creek at Auburn, Ind.	1,520	4	840	1,650	1,850	9.20	847.14

TABLE 2–3(continued) Flood Characteristics of Streams

Station No. 4-	Stream and Station	Instantaneous Flows of Record (cfs)	Instantaneous Flows of Record (% prob)	Discharge Frequency 2-year (cfs)	Discharge Frequency 50-year (cfs)	Discharge Frequency 100-year (cfs)	Gage Height of Record (ft)	1929 Datum Gage Zero (ft)
Lake Erie Southwest--Planning Subarea 4.2 (continued)								
1800	Cedar Creek Near Cedarville, Ind.	4,870	10.5	2,750	6,100	6,650	11.67	780.09
1815	St. Marys River at Decatur, Ind.	11,300	5.5	5,500	14,250	16,250	24.22	760.44
1820	St. Marys River Near Ft. Wayne, Ind.	13,600	3.5	5,800	15,400	17,500	19.42	748.97
1830	Maumee River at New Haven, Ind.	19,100	4	12,250	20,500	22,000	21.4	724.51
1835	Maumee River at Antwerp, Ohio	26,200	3	12,500	28,500	33,000	20.29	694.90
1845	Bean Creek at Powers, Ohio	4,250	8.5	2,000	6,000	6,950	13.82	722.57
1850	Tiffin River at Stryker, Ohio	6,640	2.5	2,850	9,200	10,750	16.16	685.1
1865	Auglaize River Near Jennings, Ohio	12,000	3.5	4,700	13,500	15,600	20.30	713.6
1875	Ottawa River at Allentown, Ohio	7,740	2	3,000	7,950	8,950	10.88	789.14
1890	Blanchard River Near Findlay, Ohio	15,000	2	4,850	15,000	17,500	16.76	754.55
1891	Tiderishi Creek Near Jenera, Ohio	-	-	175	630	750	-	-
1905	Roller Creek at Ohio City, Ohio	-	-	215	580	670	-	-
1915	Auglaize River Near Defiance, Ohio	52,500	4.5	23,500	63,000	73,000	26.4	659.70
1925	Maumee River Near Defiance, Ohio	87,100	5.8	44,000	100,900	125,000	11.00	659.12
1935	Maumee River at Waterville, Ohio	94,000	5	48,000	110,000	125,000	14.52	595.71
1960	Sandusky River Near Bucyrus, Ohio	5,800	4.0	2,430	6,800	7,850	9.15	955.04
1965	Sandusky River Near Upper Sandusky, Ohio	10,000	6.0	4,600	12,800	14,900	15.00	792.25
1970	Sandusky River Near Mexico, Ohio	19,000	6.3	8,100	25,700	30,000	22.5	733.1[c]
1980	Sandusky River Near Fremont, Ohio	28,000	9.8	14,200	40,200	49,000	15.20	626.3[c]
1990	Huron River at Milan, Ohio	48,900	0.28	9,800	31,800	37,500	31.1	573.43[c]
1995	Vermilion River Near Vermilion, Ohio	40,800	1.9	6,850	40,000	51,500	17.14	594.91
Lake Erie Central--Planning Subarea 4.3								
2005	Black River at Elyria, Ohio	51,700	0.2	7,900	23,700	27,800	26.4	621.6[d]
2015	Rocky River Near Berea, Ohio	21,400	1.1	8,150	19,400	22,000	20.9	649.9
2060	Cuyahoga River at Old Portage, Ohio	6,500	0.47	2,900	5,450	5,950	11.54	740.11[e]
2080	Cuyahoga River at Independence, Ohio	24,800	0.2	8,300	17,200	19,000	22.41	584.14[e]
2090	Chagrin River at Willoughby, Ohio	28,000	1.7	9,500	28,800	33,200	17.95	594.24
2115	Mill Creek Near Jefferson, Ohio	9,810	0.43	3,400	7,700	8,600	12.50	822.59[f]
2120	Grand River Near Madison, Ohio	21,100	0.8	8,900	18,300	20,300	14.73	674.47[c]

TABLE 2-3(continued) Flood Characteristics of Streams

Station No. 4-	Stream and Station	Instantaneous Flows of Record (cfs)	Instantaneous Flows of Record (% prob)	Discharge Frequency 2-year (cfs)	Discharge Frequency 50-year (cfs)	Discharge Frequency 100-year (cfs)	Gage Height of Record (ft)	1929 Datum Gage Zero (ft)
Lake Erie Central--Planning Subarea 4.3 (continued)								
2125	Ashtabula River Near Ashtabula, Ohio	11,600	2.0	4,400	11,600	13,300	11.03	612.5[e]
2130	Conneaut Creek at Conneaut, Ohio	17,000	1.5	5,900	16,000	18,500	12.94	610.3[e]
Lake Erie East--Planning Subarea 4.4								
2135	Cattaraugus Creek at Gowanda, N.Y.	35,900	3.4	15,500	40,000	46,000	14.14	738.74[g]
2145	Buffalo Creek at Gardenville, N.Y.	13,000	5.0	7,000	15,300	17,000	11.90	604.04[e]
2150	Cayuga Creek Near Lancaster, N.Y.	8,750	6.5	5,200	10,500	11,700	12.58	672.80[e]
2155	Cazenovia Creek at Ebenezer, N.Y.	13,500	3.0	6,800	14,400	16,000	15.82	604.86[e]
2165	Little Tonawanda Creek at Linden, N.Y.	2,700	3.0	1,010	2,950	3,440	16.04	1081.62
2170	Tonawanda Creek at Batavia, N.Y.	7,200	6.8	3,740	9,250	10,500	13.85	876.01[h]
Lake Ontario West--Planning Subarea 5.1								
2215	Genesee River at Scio, N.Y.	23,300	1.7	7,500	22,600	26,500	11.22	1438.83
2230	Genesee River at Portageville, N.Y.[k]	44,400	3.5	22,200	48,800	54,500	12.81	1082.60[i]
2250	Canaseraga Creek Near Dansville, N.Y.	9,110	5.6	3,900	11,800	13,800	13.68	640.00[j]
2275	Genesee River[m] at	55,100	0.95	21,800	48,700	54,800	25.44	540.00[j]
	Jones Bridge[n]	13,800	5.3	10,300	15,100	16,000	25.44	-
2305	Oatka Creek at Garbutt, N.Y.	6,920	3.5	2,280	8,000	9,600	8.64	560.89[i]
2310	Black Creek at Churchville, N.Y.	4,880	1.0	1,370	4,150	4,880	9.44	552.45[i]
2320	Genesee River at Driving	48,300	0.4	22,500	40,200	44,000	17.08	247[o]
	Park, Rochester, N.Y.[m]	25,800	4.8	16,800	28,800	31,000	17.08	
Lake Ontario Central--Planning Subarea 5.2								
2330	Cayuga Inlet Near Ithaca, N.Y.	4,110	4.5	1,280	5,250	6,400	7.58	437.16[i]
2340	Fall Creek Near Ithaca, N.Y.	15,500	0.08	3,190	8,800	10,200	9.52	794.81[c]
2425	East Br. Fish Creek at Taberg, N.Y.	13,600	0.9	6,790	12,400	13,500	10.90	491.12
2435	Oneida Creek at Oneida, N.Y.	7,440	11.0	3,230	13,500	16,500	14.30	409.33[i]
2440	Chittenango Creek Near Chittenango, N.Y.	2,690	12.5	1,500	4,350	5,130	7.18	489.54
2450	Limestone Creek at Fayetteville, N.Y.	7,010	5.3	2,580	9,350	11,300	7.95	427.62[i]
Lake Erie Ontario East--Planning Subarea 5.3								
2525	Black River Near Boonville, N.Y.	12,400	0.3	5,450	9,900	10,700	12.5	935.50
2560	Independence River at Donnattsburg, N.Y.	3,410	3.2	1,830	3,650	4,000	8.8	972.84

TABLE 2–3(continued) Flood Characteristics of Streams

Station No. 4-	Stream and Station	Instantaneous Flows of Record (cfs)	(% prob)	Discharge Frequency 2-year (cfs)	50-year (cfs)	100-year (cfs)	Gage Height of Record (ft)	1929 Datum Gage Zero (ft)
Lake Erie Ontario East--Planning Subarea 5.3								
2625	West Br. Oswegatchie River Near Harrisville, N.Y.	6,920	2.7	3,980	7,200	7,800	9.6	738.51
2650	Grass River at Pyrites, N.Y.	8,300	2.8	4,550	8,700	9,600	13.0	350.61
2690	St. Regis River at Brasher Center,N.Y.	16,800	1.4	7,400	15,900	17,600	15.3 (ice jam)	217.23

[a]At different site and (or) datum. See station description.

[b]Affected by backwater.

[c]1912 datum.

[d]City of Elyria BM.

[e]Unadjusted.

[f]Ashtabula Co. BM.

[g]Village of Gowanda BM.

[h]Batavia BM.

[i]Corps of Engineers.

[j]N.Y.S. Conservation Comm.

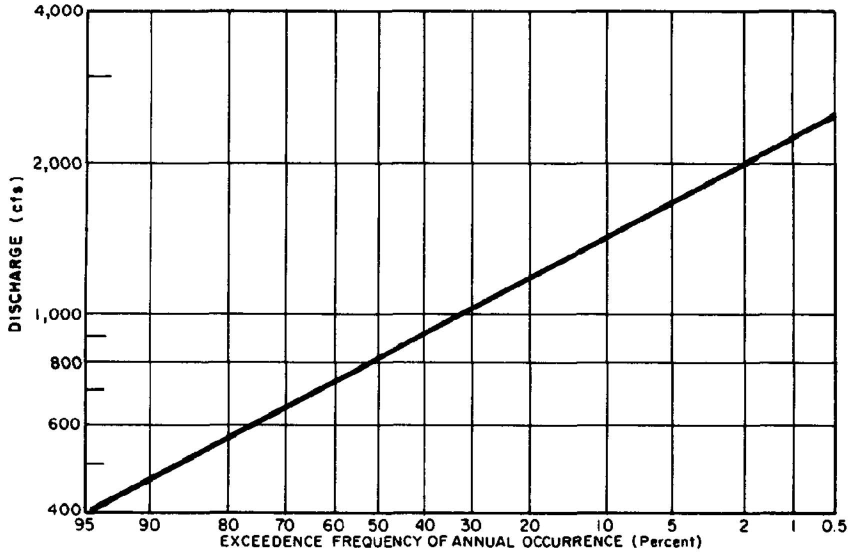
[k]Prior to 1945 gage record published as "at St. Helena".

[l]Prior to 1920 gage record published as "at Rochester".

[m]Pertinent data based on period of record prior to construction of Mt. Morris Dam.

[n]Pertinent data based on period of record subsequent to construction of Mt. Morris Dam. Drainage area regulated by Mt. Morris Dam is 1,075 square miles.

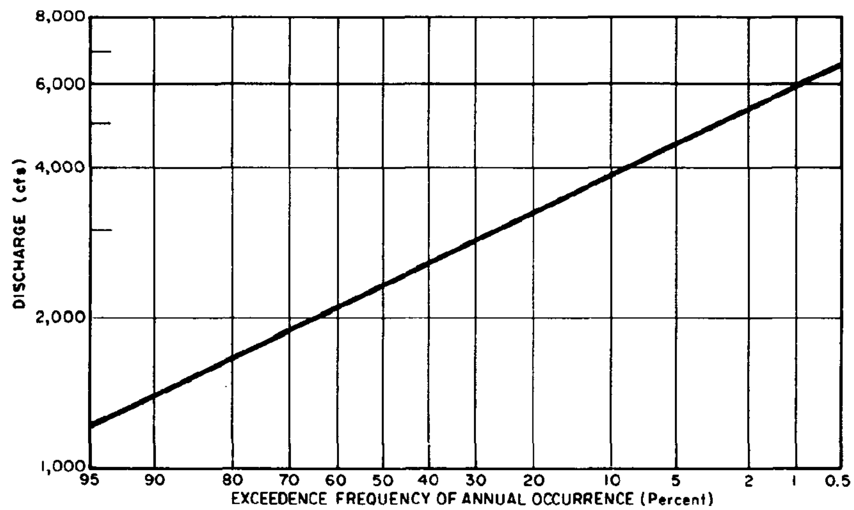
[o]Barge Canal Datum.



DRAINAGE AREA (SQ. MI.)	100	200	300	400	500
FACTOR MULTIPLIER	.95	2.25	4.20	6.40	8.90

DRAINAGE AREA ADJUSTMENT FACTORS

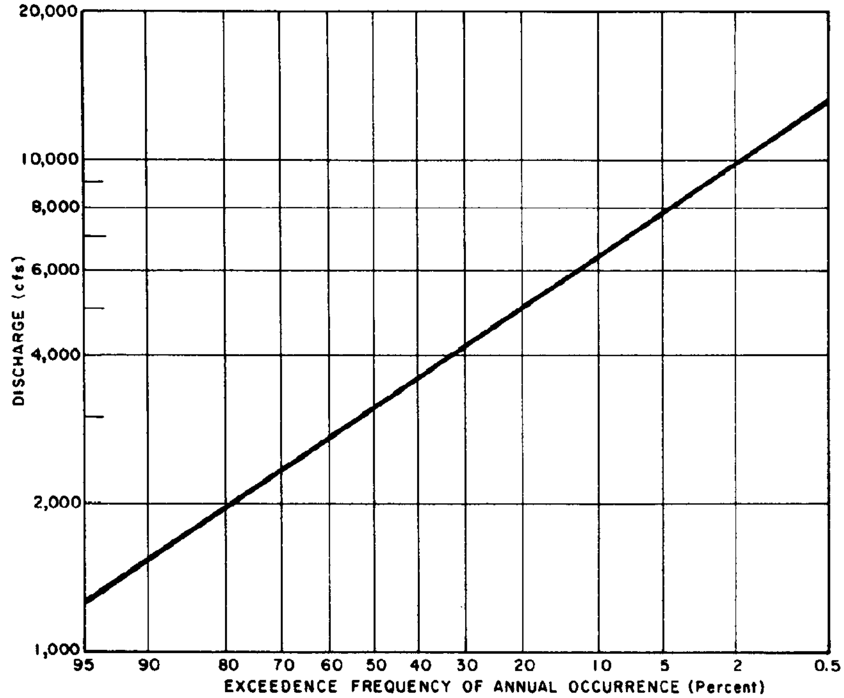
FIGURE 2–20 Peak Discharge Frequency Curve, Planning Subarea 1.1, Poplar River at Lutsen, Minn. (114 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ. MI.)	100	200	300	400	500
FACTOR MULTIPLIER	.60	1.15	1.75	2.35	2.95

DRAINAGE AREA ADJUSTMENT FACTORS

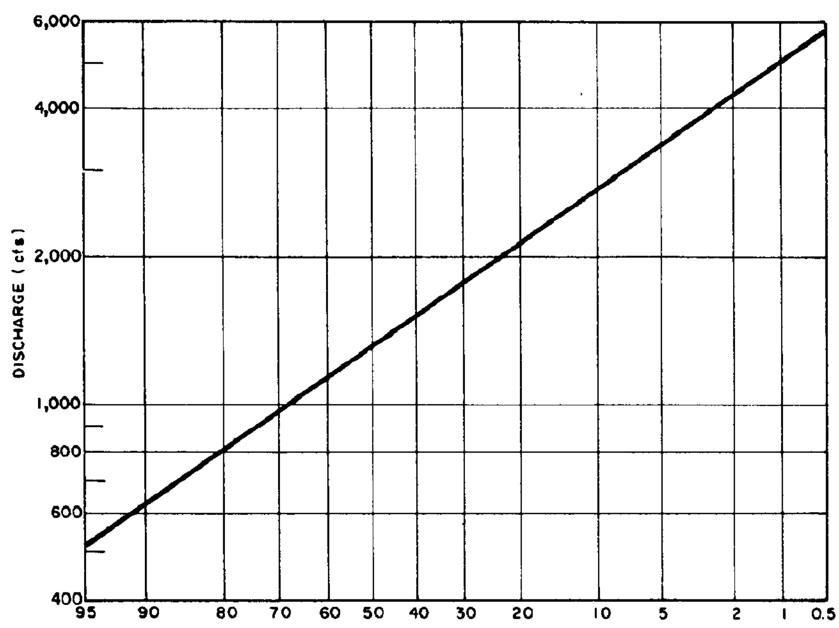
FIGURE 2–21 Peak Discharge Frequency Curve, Planning Subarea 1.2, Sturgeon River Near Sidnaw, Mich. (171 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	200	400	600	800	1000
FACTOR MULTIPLIER	.40	.80	1.20	1.50	1.80

DRAINAGE AREA ADJUSTMENT FACTORS

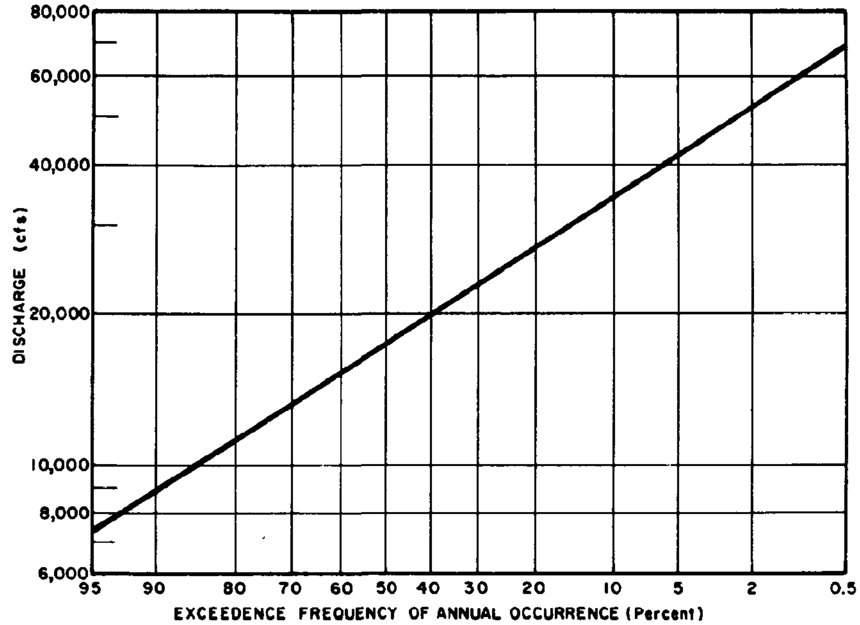
FIGURE 2–22 Peak Discharge Frequency Curve, Planning Subarea 2.1, Little Wolf River at Royalton, Wis. (514 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	50	100	150	200	250
FACTOR MULTIPLIER	.45	.85	1.20	1.50	1.80

DRAINAGE AREA ADJUSTMENT FACTORS

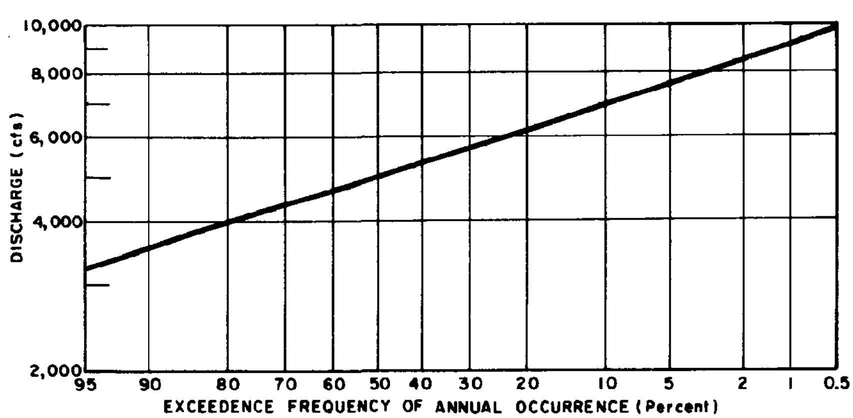
FIGURE 2–23 Peak Discharge Frequency Curve, Planning Subarea 2.2, Deep River at Lake George Outlet At Hobart, Ind. (125 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	1000	2000	3000	4000	5000
FACTOR MULTIPLIER	.20	.40	.60	.80	1.05

DRAINAGE AREA ADJUSTMENT FACTORS

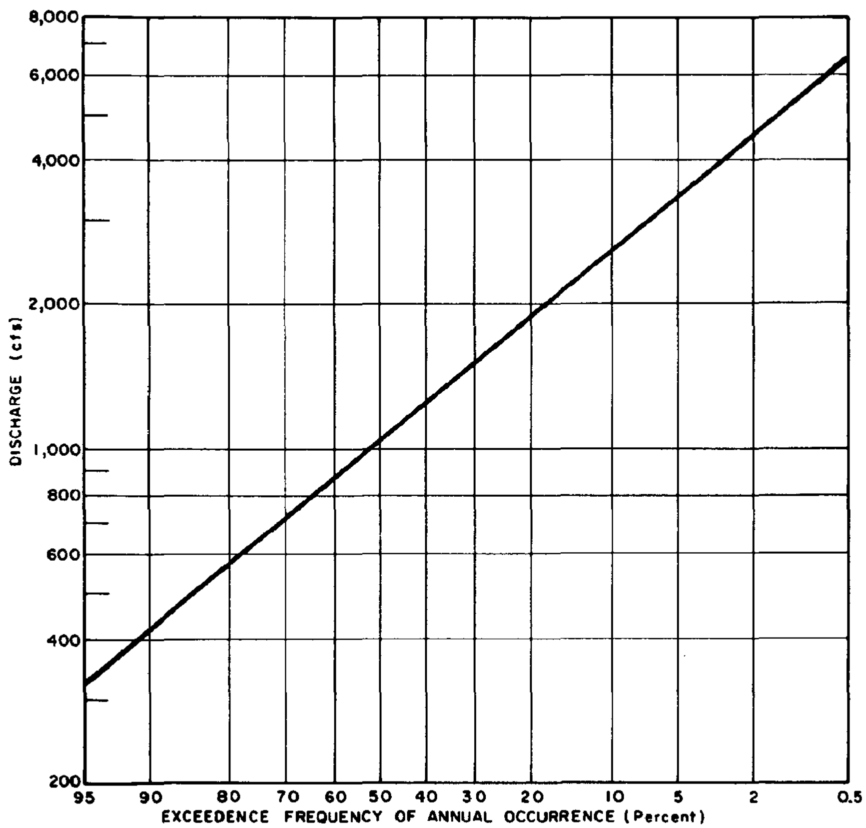
FIGURE 2–24 Peak Discharge Frequency Curve, Planning Subarea 2.3, Grand River at Grand Rapids, Mich. (4,900 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	400	800	1200	1600	2000
FACTOR MULTIPLIER	.25	.50	.70	.90	1.10

DRAINAGE AREA ADJUSTMENT FACTORS

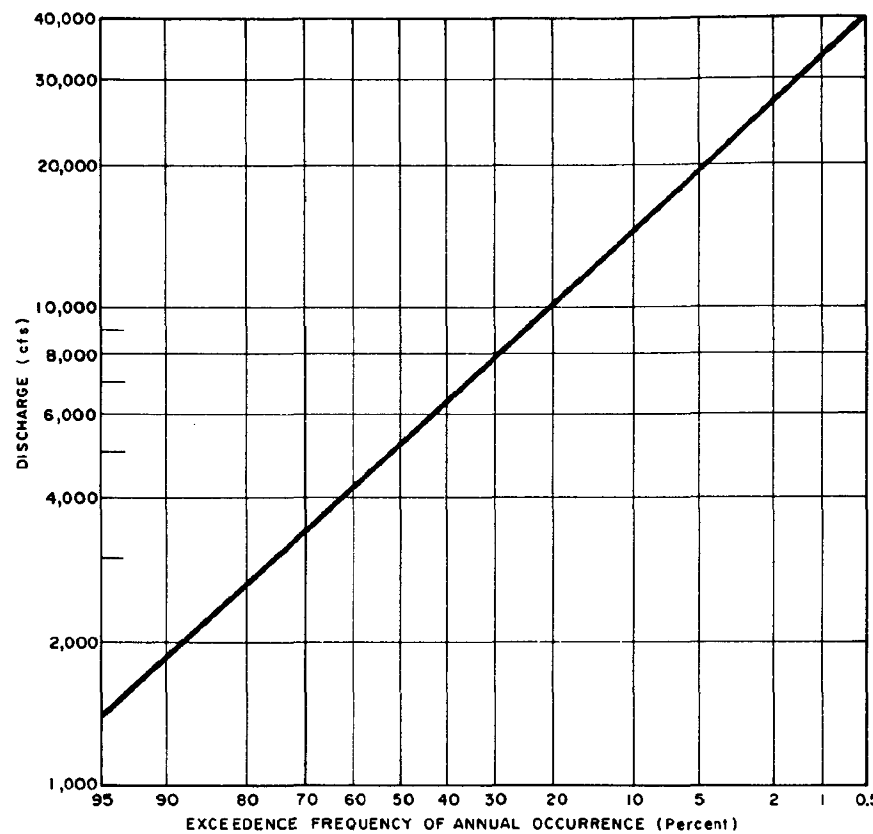
FIGURE 2–25 Peak Discharge Frequency Curve, Planning Subarea 2.4, Manistee River Near Manistee, Mich. (1,780 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	50	100	150	200	250
FACTOR MULTIPLIER	.35	.65	.90	1.15	1.40

DRAINAGE AREA ADJUSTMENT FACTORS

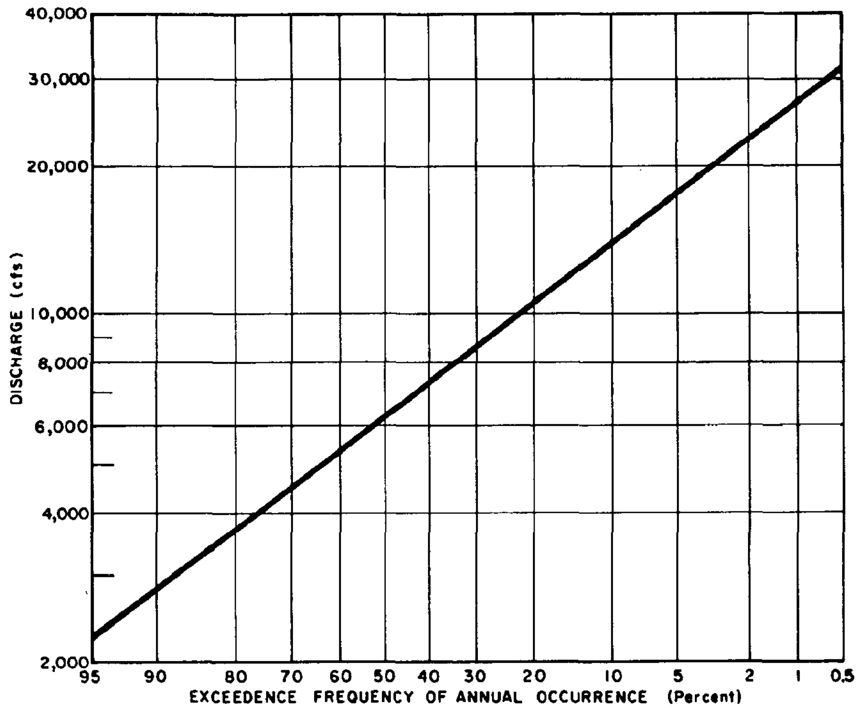
FIGURE 2–26 Peak Discharge Frequency Curve, Planning Subarea 3.1, Au Gres River Near National City, Mich. (169 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	200	400	600	800	1000
FACTOR MULTIPLIER	.35	.65	.90	1.15	1.35

DRAINAGE AREA ADJUSTMENT FACTORS

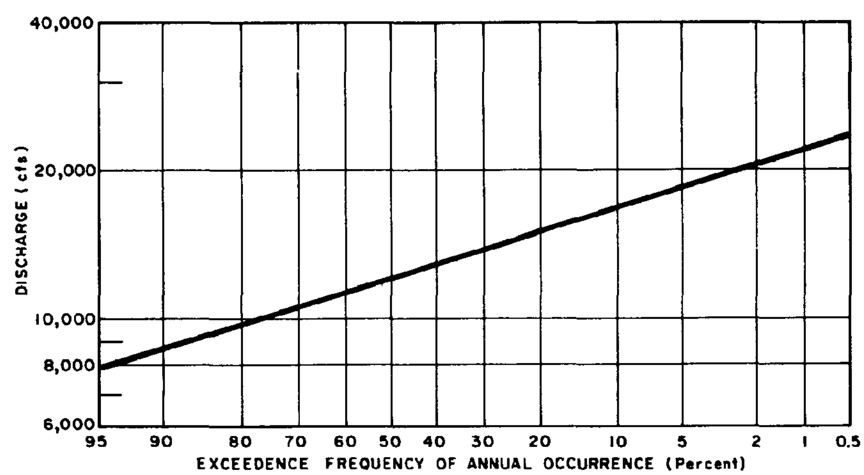
FIGURE 2–27 Peak Discharge Frequency Curve, Planning Subarea 3.2, Cass River at Vassar, Mich. (700 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	200	400	600	800	1000
FACTOR MULTIPLIER	.35	.60	.85	1.10	1.35

DRAINAGE AREA ADJUSTMENT FACTORS

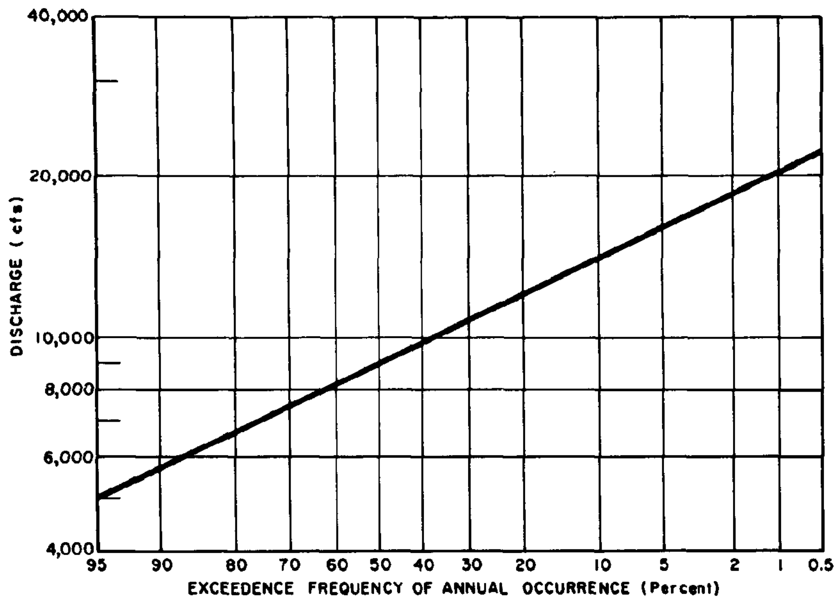
FIGURE 2-28 Peak Discharge Frequency Curve, Planning Subarea 4.1, Clinton River at Mt. Clemens, Mich. (734 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	400	800	1200	1600	2000
FACTOR MULTIPLIER	.25	.45	.65	.85	1.05

DRAINAGE AREA ADJUSTMENT FACTORS

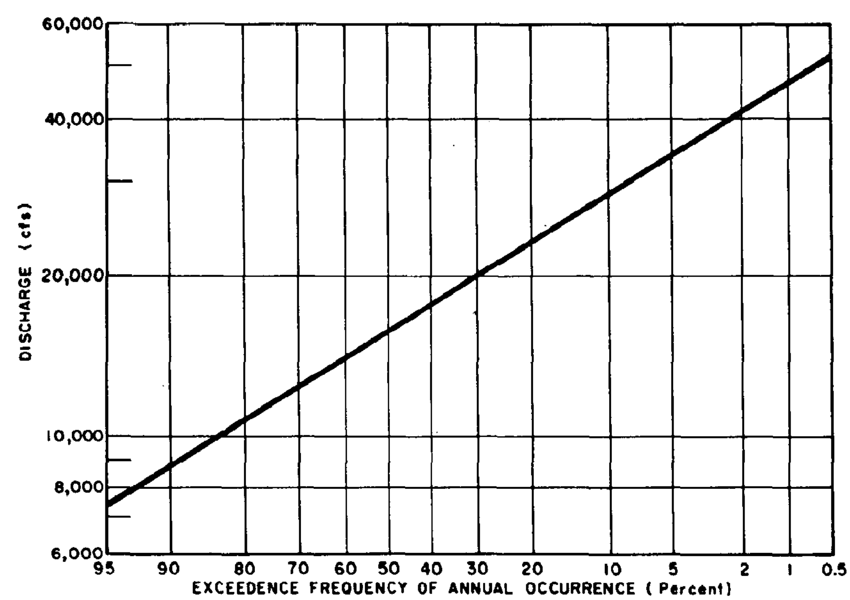
FIGURE 2-29 Peak Discharge Frequency Curve, Planning Subarea 4.2, Maumee River at New Haven, Ind. (1,966 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	200	400	600	800	1000
FACTOR MULTIPLIER	.45	.75	1.05	1.25	1.45

DRAINAGE AREA ADJUSTMENT FACTORS

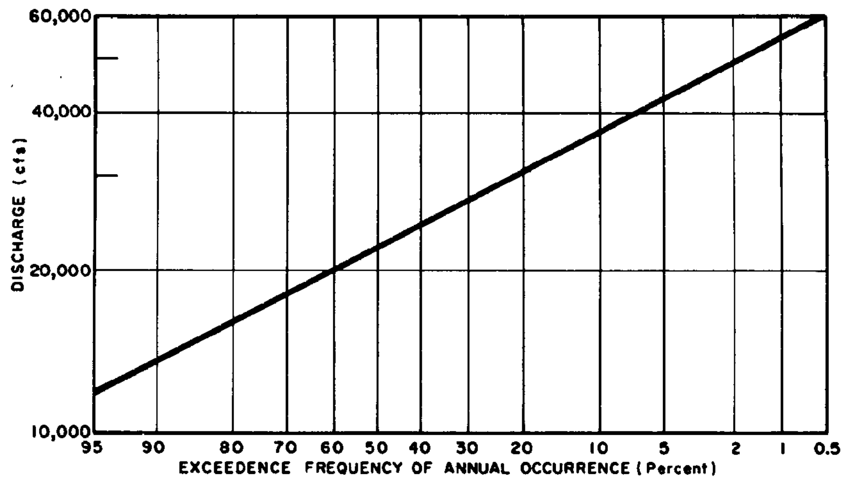
FIGURE 2–30 Peak Discharge Frequency Curve, Planning Subarea 4.3, Grand River at Madison, Ohio (581 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	100	200	300	400	500
FACTOR MULTIPLIER	.35	.55	.75	.95	1.10

DRAINAGE AREA ADJUSTMENT FACTORS

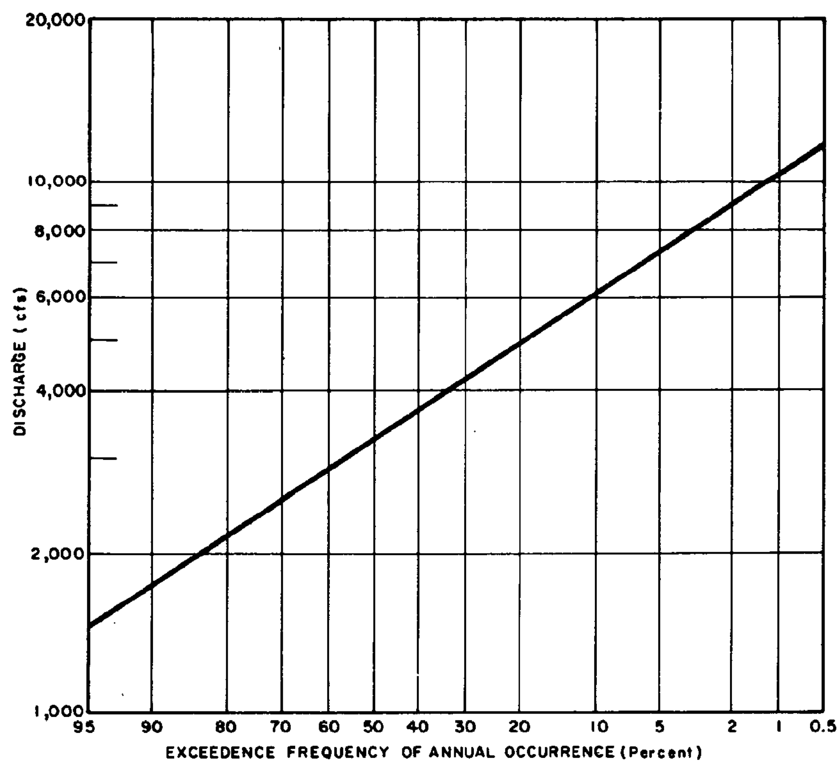
FIGURE 2–31 Peak Discharge Frequency Curve, Planning Subarea 4.4, Cattaraugus Creek at Gowanda, N.Y. (432 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	400	800	1200	1600	1800
FACTOR MULTIPLIER	.50	.85	1.15	1.45	1.75

DRAINAGE AREA ADJUSTMENT FACTORS

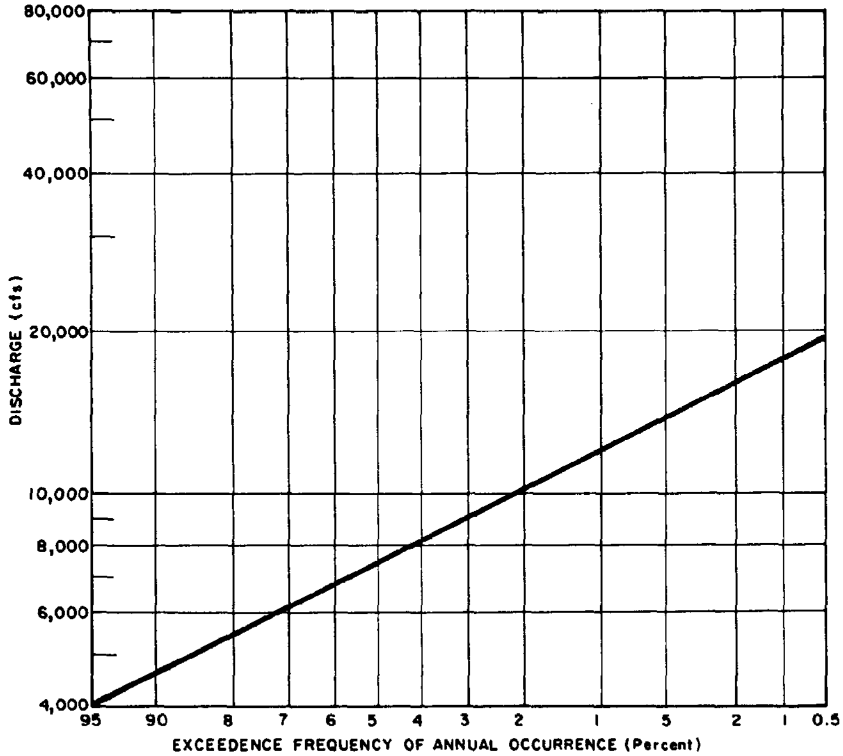
FIGURE 2–32 Peak Discharge Frequency Curve, Planning Subarea 5.1, Genesee River at Portageville, N.Y. (961 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	200	400	600	800	1000
FACTOR MULTIPLIER	1.40	2.30	3.20	4.00	4.80

DRAINAGE AREA ADJUSTMENT FACTORS

FIGURE 2–33 Peak Discharge Frequency Curve, Planning Subarea 5.2, Fall Creek Near Ithaca, N.Y. (126 Sq. Mi. Drainage Area)



DRAINAGE AREA (SQ.MI.)	400	800	1200	1600	2000
FACTOR MULTIPLIER	.70	1.30	1.90	2.50	3.10

DRAINAGE AREA ADJUSTMENT FACTORS

FIGURE 2–34 Peak Discharge Frequency Curve, Planning Subarea 5.3, St. Regis River at Brasher Center, N.Y. (616 Sq. Mi. Drainage Area)

Section 4

DROUGHT FLOWS

4.1 General

Low-flow data are important for design of water supplies, waste treatment plants, hydroelectric power, agricultural and industrial operations, low-flow releases, and recreation. Sustained low flows may require development of additional sources of supply such as ground-water or storage reservoirs (see Appendix 3, *Geology and Ground Water)*. An analysis of drought flows may also help municipal and industrial water users plan alternative programs such as recirculation and improved water management. A knowledge of a stream's low-flow characteristics is extremely important before meaningful legal appropriation of its water can take place. Not only is it important to know the rate of low flow but its duration and volume must also be determined.

4.2 Seasonal Occurrences

Low flows occur each year on streams throughout the Basin as runoff diminishes due to increased losses by evapotranspiration and seasonal variances in rainfall distributions. Runoff within the Great Lakes Basin is usually lowest in the months of August and September. Several stations also experience low flows in January and February during the winter freeze-up. Instantaneous minimums have occurred at various locations in the Basin in all months, but predominantly in July through October. However, a prolonged low flow may be more critical than the lowest instantaneous discharge during a given period.

After surface runoff ceases, the entire flow of the stream is drawn from ground-water storage. As this storage is depleted, the streamflow diminishes until either the stream goes dry or the supply is replenished by precipitation. These replenishing rains are often local, some covering an area of only a few square miles. Scores of such rains may fall on various portions of a large drainage basin during a given drought, although many of the small component basins may be left untouched. Because each of these local rains contributes to the discharge of the main stream, larger basins are likely to provide a more sustained flow than smaller ones.

4.3 Low-Flow Frequencies

The low-flow characteristics of a stream can be evaluated through the use of a low-flow discharge-frequency statistical analysis of streamflow records. As available streamflow records on most of the tributaries to the Great Lakes cover relatively short periods, a reliable picture of the drought regimen cannot always be obtained from an examination of low-streamflow records alone. Therefore, any investigation of droughts should include a thorough search of historical records in newspaper files, historical society libraries, long-term climatological records, and other sources.

As the low-flow data contained in this section are derived entirely from streamflow records, they may be somewhat misleading in presenting an accurate evaluation of the extreme drought, especially if a known drought occurred outside of the period of record. Because droughts are always associated with periods of deficient precipitation, an examination of rainfall records is also valuable. Rainfall records usually cover many more years than streamflow records. Low-flow frequency curves based on nonexceedence frequency for selected durations at hydrologic stations in each planning subarea are shown in Figures 2–35 through 2–49. The figures include only that part of the range that is applicable. Additional low-flow data for selected stations are tabulated in Table 2–4, which lists the 1- and 7-day duration low-flow of record along with the 7-day, 10-year low-flow, and the 1-day, 30-year low-flow frequency values. In addition, the lowest instantaneous observed flow of record is shown. Working papers filed in the Great Lakes Basin Commission office also contain the 1-day, 50-year low-flow frequency values for each hydrologic station. The low flow of record data tabulated in Table 2–4 represent the lowest average flow ever recorded at that station for either a 1-day or 7-day continuous period. The nonexceedence frequency data refer to the lowest average 1-day or 7-day low flow expected to have a 3.3-percent and 10-percent chance, respectively, of occurring in any one year.

TABLE 2–4 Low Flow Discharge Frequency at Selected Gaging Stations

Station No. 4-	Stream and Station	Low Flow of Record 1-Day (cfs)	1-Day 30-Year (cfs)	Low Flow of Record 7-Day (cfs)	7-Day 10-Year (cfs)	Instantaneous Lowest Observed Flow of Record (cfs)
Lake Superior West-Planning Subarea 1.1						
105	Pigeon River at Middle Falls, Minnesota	33.6	36.0	33.6	46.0	27.0
125	Poplar River at Lutsen, Minnesota	4.8	5.2	7.1	8.4	2.3
145	Baptism River at Beaver Bay, Minnesota	0.4	1.2	0.9	2.7	0.4
170	Embarrass River at Embarrass, Minnesota	0.9	0.78	0.9	1.7	0.9
255	Bois Brule River at Brule, Wisconsin	88.0	90.0	94.0	102.0	67.0
270	Bad River at Odanah, Wisconsin	52.0	48.0	54.0	66.0	49.0
275	White River at Ashland, Wisconsin	72.0	68.0	129.0	129.0	3.1
300	Montreal River at Saxon, Wisconsin	7.0	10.0	8.0	26.0	2.0
Lake Superior East-Planning Subarea 1.2						
320	Presque Isle River near Tula, Michigan	22.0	24.0	23.7	30.5	22.0
405	Sturgeon River near Sidnaw, Michigan	4.8	5.3	5.3	8.3	4.6
425	Otter River near Elo, Michigan	71.0	68.0	73.1	75.5	68.0
430	Sturgeon River near Arnheim, Michigan	157.0	167.0	168.0	209.0	157.0
455	Tahquamenon River near Paradise, Michigan	174.0	170.0	184.0	190.0	157.0
Lake Michigan Northwest-Planning Subarea 2.1						
590	Escanaba River at Cornell, Michigan	100.0	105.0	159.0	163.0	90.0
610	Brule River near Florence, Wisconsin	-	135.0	-	158.0	118.0
645	Pine River at Pine River Power Plant near Florence, Wisconsin	0.10	-	41.0	-	0
660	Menominee River near Pembine, Wis.	1,000.0	950.0	1,090.0	1,110.0	708.0
665	Pike River at Amberg, Wisconsin	26.0	45.0	53.0	72.0	26.0
680	Peshtigo River at High Falls near Crivitz, Wisconsin	0.10	-	-	8.0	0
710	Oconto River near Gillett, Wisconsin	116.0	145.0	152.0	179.0	93.0
735	Fox River at Berlin, Wisconsin	248.0	270.0	266.0	337.0	248.0
755	Wolf River above West Branch Wolf River, Wisconsin	199.0	195.0	217.0	227.0	199.0
770	Wolf River at Keshena Falls, Wisconsin	194.0	240.0	260.0	305.0	91.0
785	Embarrass River near Embarrass, Wisconsin	24.0	28.0	27.0	47.0	23.0
790	Wolf River at New London, Wisconsin	216.0	290.0	337.0	467.0	150.0
800	Little Wolf River at Royalton, Wisconsin	55.0	68.0	74.0	98.0	52.0
810	Waupaca River near Waupaca, Wisconsin	50.0	72.0	103.0	117.0	38.0
860	Sheboygan River at Sheboygan, Wis.	1.0	3.3	9.0	13.0	1.0
865	Cedar Creek near Cedarburg, Wisconsin	0.2	0.28	0.2	1.0	0.2
870	Milwaukee River at Milwaukee, Wisconsin	1.0	2.2	8.0	22.0	0

TABLE 2–4(continued) Low Flow Discharge Frequency at Selected Gaging Stations

Station No. 4-	Stream and Station	Low Flow of Record 1-Day (cfs)	1-Day 30-Year (cfs)	Low Flow of Record 7-Day (cfs)	7-Day 10-Year (cfs)	Instantaneous Lowest Observed Flow of Record (cfs)
Lake Michigan Southwest-Planning Subarea 2.2						
905	Thorn Creek at Thornton, Illinois	4.4	4.9	9.5	10.8	4.4
910	Little Calumet River at South Holland, Illinois	8.0	8.8	14.3	18.0	7.9
930	Deep River at Lake George Outlet at Hobart, Indiana	4.2	2.8	5.0	4.8	2.0
940	Little Calumet River at Porter, Indiana	17.0	17.0	18.7	18.8	15.0
945	Salt Creek at McCool, Indiana	14.0	15.5	14.9	19.4	6.3
Lake Michigan Southeast-Planning Subarea 2.3						
975	St. Joseph River at Three Rivers, Michigan	78.0	78.0	126.0	190.0	0
990	St. Joseph River at Mottville, Michigan	39.0	120.0	278.0	342.0	0
995	Pigeon Creek at Hogback Lake near Angola, Indiana	3.4	3.1	3.5	6.4	3.4
1002.2	North Branch Elkhart River near Cosperville, Indiana	2.2	1.5	3.2	4.2	2.2
1005	Elkhart River at Goshen, Indiana	7.0	20.0	49.6	76.0	6.6
1010	St. Joseph River at Elkhart, Indiana	336.0	380.0	561.0	750.0	0
1015	St. Joseph River at Niles, Michigan	420.0	340.0	728.0	930.0	0
1025	Paw Paw River at Riverside, Michigan	120.0	120.0	134.0	143.0	99.0
1035	Kalamazoo River at Marshall, Michigan	31.0	30.0	59.4	82.0	12.0
1050	Battle Creek at Battle Creek, Michigan	22.0	23.0	24.7	32.0	0
1055	Kalamazoo River near Battle Creek, Michigan	86.0	100.0	106.0	165.0	0
1060	Kalamazoo River at Comstock, Michigan	185.0	170.0	217.0	250.0	119.0
1085	Kalamazoo River near Fennville, Michigan	73.0	135.0	257.0	400.0	0
1090	Grand River at Jackson, Michigan	12.0	13.0	14.0	22.0	9.2
1110	Grand River near Eaton Rapids, Michigan	21.0	21.0	52.4	64.0	14.0
1125	Red Cedar River at East Lansing, Michigan	3.0	3.7	3.9	8.0	3.0
1130	Grand River at Lansing, Michigan	20.0	28.0	44.4	70.0	2.8
1140	Grand River at Portland, Michigan	58.0	55.0	85.3	105.0	38.0
1145	Looking Glass River near Eagle, Michigan	11.0	11.0	11.0	15.0	10.0
1150	Maple River at Maple Rapids, Michigan	4.8	47.0	5.7	9.0	4.4
1160	Grand River at Ionia, Michigan	115.0	120.0	155.0	180.0	105.0
1165	Flat River at Smyrna, Michigan	70.0	72.0	114.0	120.0	7.4
1175	Thornapple River near Hastings, Michigan	35.0	36.0	36.4	48.0	33.0
1180	Thornapple River near Caledonia, Michigan	4.7	63.0	87.1	114.0	2.2
1185	Rogue River near Rockford, Michigan	49.0	49.0	58.1	68.0	28.0
1190	Grand River at Grand Rapids, Michigan	381.0	500.0	438.0	670.0	0
Lake Michigan Northeast-Planning Subarea 2.4						
460	Black River near Garnet, Michigan	5.4	5.5	5.7	6.3	4.9
550	Manistique River near Blaney, Michigan	188.0	190.0	194.0	220.0	182.0
565	Manistique River near Manistique, Michigan	290.0	290.0	294.0	340.0	288.0
590	Escanaba River at Cornell, Michigan	150.0	105.0	174.0	165.0	90.0

TABLE 2-4(continued) Low Flow Discharge Frequency at Selected Gaging Stations

Station No. 4-	Stream and Station	Low Flow of Record 1-Day (cfs)	1-Day 30-Year (cfs)	Low Flow of Record 7-Day (cfs)	7-Day 10-Year (cfs)	Instantaneous Lowest Observed Flow of Record (cfs)
Lake Michigan Northeast-Planning Subarea 2.4 (continued)						
1210	Muskegon River near Merritt, Michigan	26.0	27.0	26.4	36.0	0
1215	Muskegon River at Evart, Michigan	252.0	260.0	274.0	300.0	164.0
1225	Pere Marquette at Scottville, Michigan	310.0	320.0	322.0	350.0	209.0
1230	Big Sable River near Freesoil, Michigan	81.0	80.0	82.6	87.0	65.0
1235	Manistee River near Grayling, Michigan	130.0	135.0	140.0	148.0	122.0
1255	Pine River near Hoxeyville, Michigan	175.0	170.0	180.0	185.0	161.0
1260	Manistee River near Manistee, Michigan	992.0	980.0	1,140.0	1,200.0	0
Lake Huron North-Planning Subarea 3.1						
1300	Cheboygan River near Cheboygan, Michigan	90.0	88.0	148.0	215.0	0
1325	Thunder Bay River near Hillman, Michigan	98.0	98.0	110.0	116.0	0
1365	Au Sable River at Mio, Michigan	456.0	440.0	533.0	570.0	18.0
1385	Au Gres River near National City, Michigan	7.0	6.7	8.4	8.7	5.9
1420	Rifle River near Sterling, Michigan	98.0	100.0	105.0	115.0	75.0
Lake Huron Central-Planning Subarea 3.2						
1440	Shiawassee River at Byron, Michigan	20.0	19.0	22.1	27.0	19.0
1445	Shiawassee River at Owosso, Michigan	2.0	4.2	7.7	19.0	0.2
1450	Shiawassee River near Fergus, Michigan	29.0	27.0	34.6	39.0	27.0
1460	Farmers Creek near Lapeer, Michigan	0.5	0.68	0.8	1.2	0
1485	Flint River near Flint, Michigan	14.0	0.24	23.1	40.0	9.0
1500	South Branch Cass River near Cass City, Michigan	0.2	-	0.4	1.0	0.2
1505	Cass River at Cass City, Michigan	0.5	0.58	0.8	1.9	0.5
1510	Cass River at Vassar, Michigan	9.6	9.4	13.7	16.0	8.6
1515	Cass River at Frankenmuth, Michigan	1.5	2.5	14.1	18.0	0
1525	Tobacco River at Beaverton, Michigan	5.9	-	52.9	78.0	5.6
1535	Salt River near North Bradley, Michigan	1.4	1.25	2.2	2.7	1.1
1540	Chippewa River near Mt. Pleasant, Michigan	19.0	30.0	49.4	68.0	12.0
1545	Chippewa River near Midland, Michigan	44.0	44.0	84.6	88.0	0
1550	Pine River at Alma, Michigan	0.4	66.0	17.9	27.0	0
1555	Pine River near Midland, Michigan	14.0	16.0	16.7	41.0	0
1560	Tittabawassee River at Midland, Michigan	111.0	106.0	126.0	170.0	39.0
Lake Erie Northwest-Planning Subarea 4.1						
1595	Black River near Fargo, Michigan	2.0	2.6	2.7	5.0	1.8
1640	Clinton River near Fraser, Michigan	49.0	50.0	59.4	66.0	47.0
1645	North Branch Clinton River near Mt. Clemens, Michigan	0.2	0.29	0.5	1.0	0.2
1655	Clinton River at Mt. Clemens, Michigan	25.0	33.0	36.7	54.0	0
1660	River Rouge at Birmingham, Michigan	0.2	0.41	0.3	1.0	1.02
1665	River Rouge at Detroit, Michigan	1.8	2.3	2.7	5.0	0

TABLE 2–4(continued) Low Flow Discharge Frequency at Selected Gaging Stations

Station No. 4–	Stream and Station	Low Flow of Record 1-Day (cfs)	1-Day 30-Year (cfs)	Low Flow of Record 7-Day (cfs)	7-Day 10-Year (cfs)	Instantaneous Lowest Observed Flow of Record (cfs)
Lake Erie Northwest-Planning Subarea 4.1 (continued)						
1670	Middle River Rouge near Garden City, Michigan	1.4	2.7	3.2	5.0	0.9
1680	Lower River Rouge at Inkster, Michigan	0.3	0.4	0.5	1.0	0.2
1695	Huron River at Commerce, Michigan	4.0	4.0	4.5	5.0	3.9
1700	Huron River at Milford, Michigan	7.2	6.4	15.9	18.0	0
1730	Huron River near Dexter, Michigan	41.0	35.0	46.6	54.0	38.0
1765	River Raisin near Monroe, Michigan	4.9	8.6	5.1	27.0	2.0
Lake Erie Southwest-Planning Subarea 4.2						
1780	St. Joseph River near Newville, Indiana	14.0	16.0	15.3	18.0	0
1795	Cedar Creek at Auburn, Indiana	0.7	0.45	0.8	2.0	0.5
1800	Cedar Creek near Cedarville, Indiana	13.0	14.5	17.6	19.0	12.0
1815	St. Marys River at Decatur, Indiana	5.4	5.2	6.2	8.0	4.7
1820	St. Marys River near Ft. Wayne, Indiana	1.0	5.4	4.9	8.0	0
1835	Maumee River at Antwerp, Ohio	26.0	51.0	45.1	66.0	24.0
1845	Bean Creek at Powers, Ohio	5.2	4.8	6.2	7.0	5.0
1850	Tiffin River at Stryker, Ohio	3.9	4.2	4.3	7.6	3.6
1875	Ottawa River at Allentown, Ohio	2.4	9.0	3.6	12.0	1.4
1890	Blanchard River near Findlay, Ohio	0.4	1.4	0.6	2.7	0
1935	Maumee River at Waterville, Ohio	26.0	32.0	49.6	74.0	20.0
1960	Sandusky River near Bucyrus, Ohio	0.6	0.55	0.8	0.8	0.4
1965	Sandusky River near Upper Sandusky, Ohio	0.6	0.72	0.7	1.4	0.5
1970	Sandusky River near Mexico, Ohio	2.0	3.3	4.5	7.0	1.8
1980	Sandusky River near Fremont, Ohio	5.0	6.6	6.6	10.8	4.4
1990	Huron River at Milan, Ohio	3.0	2.4	3.4	3.8	2.2
1995	Vermilion River near Vermilion, Ohio	0	0	0	0.1	0
Lake Erie Central-Planning Subarea 4.3						
2005	Black River at Elyria, Ohio	1.3	1.3	2.1	3.2	0
2015	Rocky River near Berea, Ohio	0.2	0.29	0.3	1.1	0.2
2060	Cuyahoga River at Old Portage, Ohio	24.0	37.0	42.0	42.9	14.0
2080	Cuyahoga River at Independence, Ohio	21.0	28.0	37.0	58.0	14.0
2090	Chagrin River at Willoughby, Ohio	3.0	4.5	7.0	11.3	3.0
2115	Mill Creek near Jefferson, Ohio	0	0	0	0	0
2120	Grand River near Madison, Ohio	0	0.08	0	0.8	0
2125	Ashtabula River near Ashtabula, Ohio	0	0	0	0	0
2130	Conneaut Creek at Conneaut, Ohio	0.3	0.5	0.6	1.4	0.2
Lake Erie East-Planning Subarea 4.4						
2135	Cattaraugus Creek at Gowanda, New York	52.0	45.0	56.0	63.0	6.0
2145	Buffalo Creek at Gardenville, New York	1.0	1.6	2.6	3.6	0.2
2150	Cayuga Creek near Lancaster, New York	0.1	0.09	0.2	0.38	0
2155	Cazenovia Creek at Ebenezer, New York	3.1	3.6	3.5	4.8	2.6
2165	Little Tonawanda Creek at Linden, New York	0.1	0.23	0.1	0.27	0.08
2170	Tonawanda Creek at Batavia, New York	0.6	0.53	1.1	2.6	0.4

TABLE 2–4(continued) Low Flow Discharge Frequency at Selected Gaging Stations

Station No. 4–	Stream and Station	Low Flow of Record 1-Day (cfs)	1-Day 30-Year (cfs)	Low Flow of Record 7-Day (cfs)	7-Day 10-Year (cfs)	Instantaneous Lowest Observed Flow of Record (cfs)
Lake Ontario West-Planning Subarea 5.1						
2215	Genesee River at Scio, New York	6.9	9.6	7.3	13.3	5.8
2230	Genesee River at Portageville, New York	32.0	33.0	39.0	51.0	18.0
2250	Canaseraga Creek near Dansville, New York	10.0	10.0	11.1	13.9	3.0
2275	Genesee River at Jones Bridge	30.0	35.0	54.4	77.0	12.0
2305	Oatka Creek at Garbutt, New York	13.0	12.0	13.6	16.0	3.3
2310	Black Creek at Churchville, New York	0.3	0.3	0.5	0.82	0.3
2320	Genesee River at Driving Park, N.Y.	91.0	180.0	104.0	350.0	10.0
Lake Ontario Central-Planning Subarea 5.2						
2330	Cayuga Inlet Near Ithaca, New York	1.9	1.8	2.2	2.5	1.7
2340	Fall Creek near Ithaca, New York	3.6	4.8	5.0	8.8	3.0
2425	East Branch of Fish Creek at Taberg, New York	5.2	6.8	6.3	14.0	4.9
2435	Oneida Creek at Oneida, New York	13.0	13.0	15.4	15.7	12.0
2440	Chittenango Creek near Chittenango, New York	10.0	9.2	11.1	11.5	9.8
2450	Limestone Creek at Fayetteville, New York	12.0	13.0	13.4	17.0	6.4
Lake Ontario East-Planning Subarea 5.3						
2525	Black River at Boonville, New York	7.0	16.0	19.3	41.5	5.0
2560	Independence River at Donnattsburg, New York	18.0	17.0	19.9	20.5	18.0
2625	West Branch Oswegatchie River near Harrisville, New York	27.0	29.0	33.6	42.0	25.0
2650	Grass River at Pyrites, New York	59.0	58.0	59.7	72.0	59.0
2690	St. Regis River at Brasher Center, New York	105.0	110.0	111.0	148.0	34.0

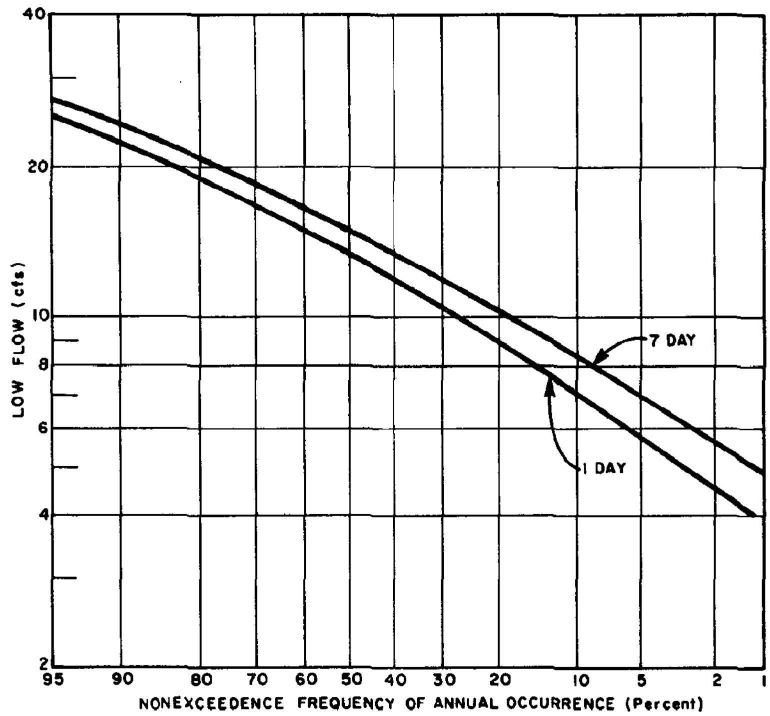


FIGURE 2–35 Low Flow Discharge Frequency Curves, Planning Subarea 1.1, Poplar River at Lutsen, Minn. (114 Sq. Mi. Drainage Area)

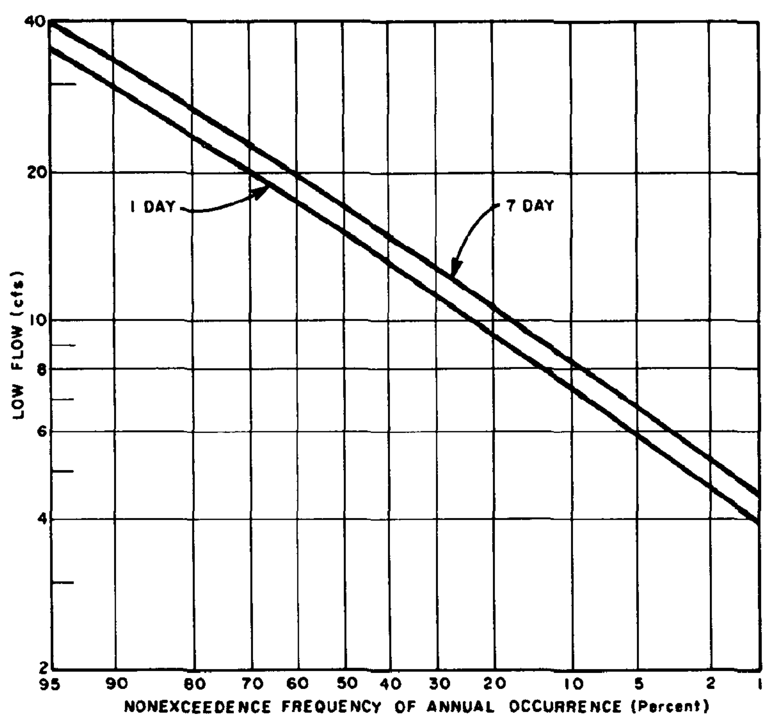


FIGURE 2–36 Low Flow Discharge Frequency Curves, Planning Subarea 1.2, Sturgeon River near Sidnaw, Mich. (171 Sq. Mi. Drainage Area)

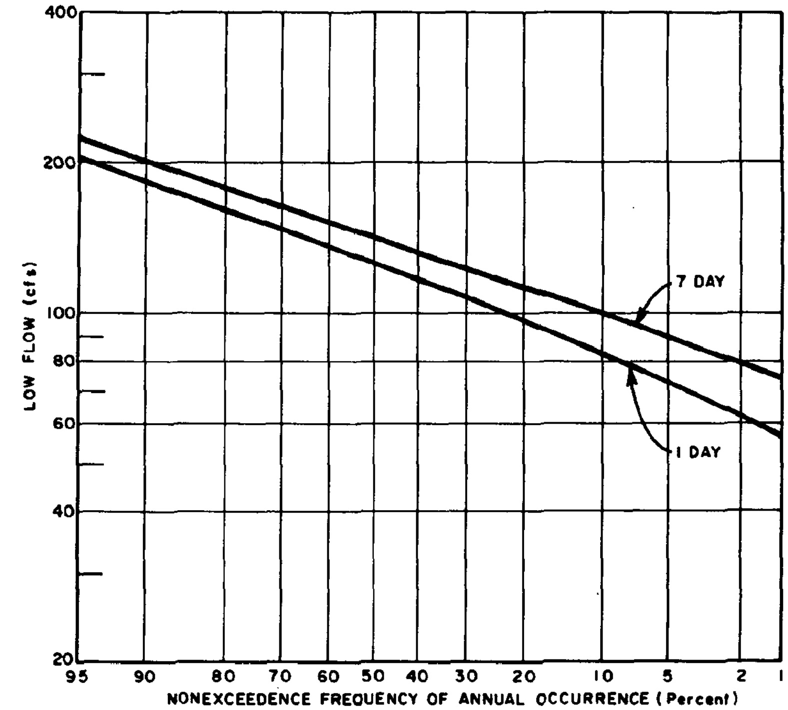


FIGURE 2–37 Low Flow Discharge Frequency Curves, Planning Subarea 2.1, Little Wolf River at Royalton, Wis. (514 Sq. Mi. Drainage Area)

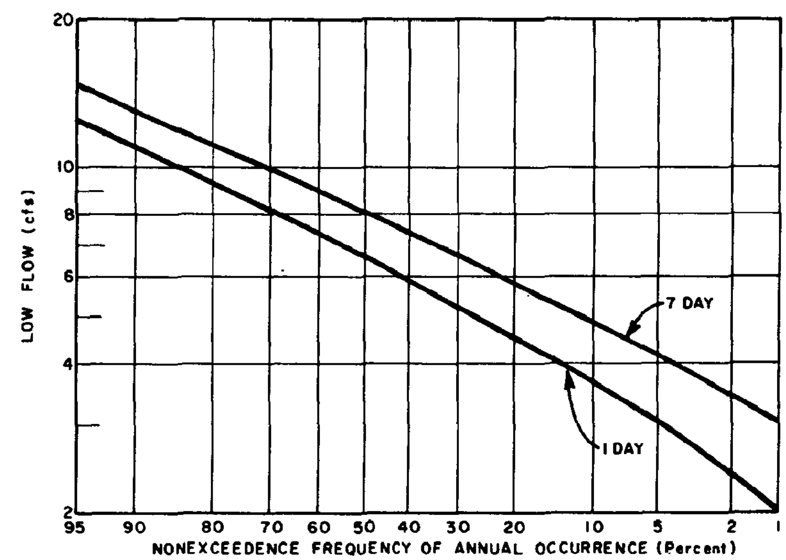


FIGURE 2–38 Low Flow Discharge Frequency Curves, Planning Subarea 2.2, Deep River at Lake George Outlet at Hobart, Ind. (125 Sq. Mi. Drainage Area)

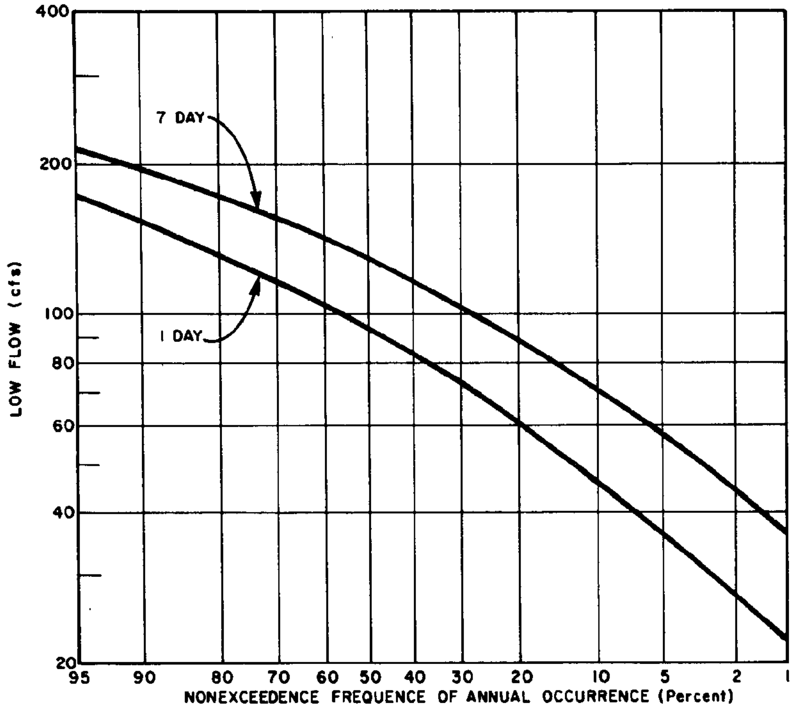


FIGURE 2–39 Low Flow Discharge Frequency Curves, Planning Subarea 2.3, Grand River at Lansing, Mich. (1,230 Sq. Mi. Drainage Area)

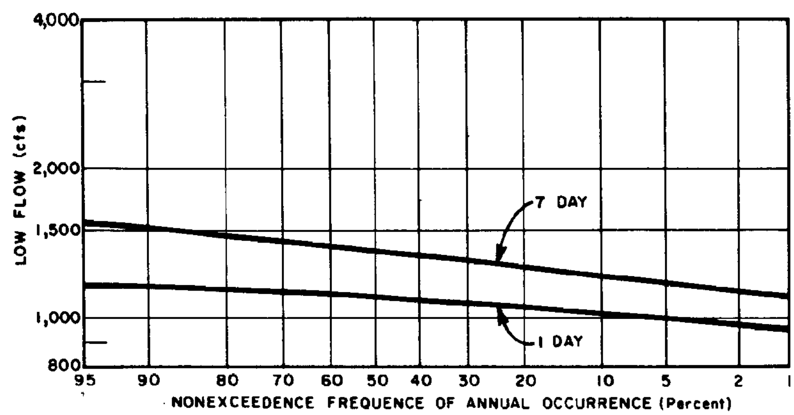


FIGURE 2–40 Low Flow Discharge Frequency Curves, Planning Subarea 2.4, Manistee River Near Manistee, Mich. (1,780 Sq. Mi. Drainage Area)

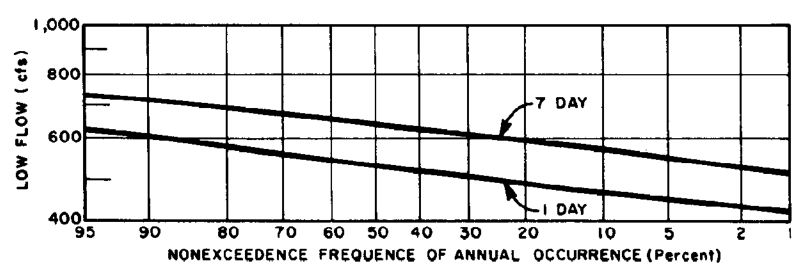


FIGURE 2–41 Low Flow Discharge Frequency Curves, Planning Subarea 3.1, Au Sable River at Mio, Mich. (1,100 Sq. Mi. Drainage Area)

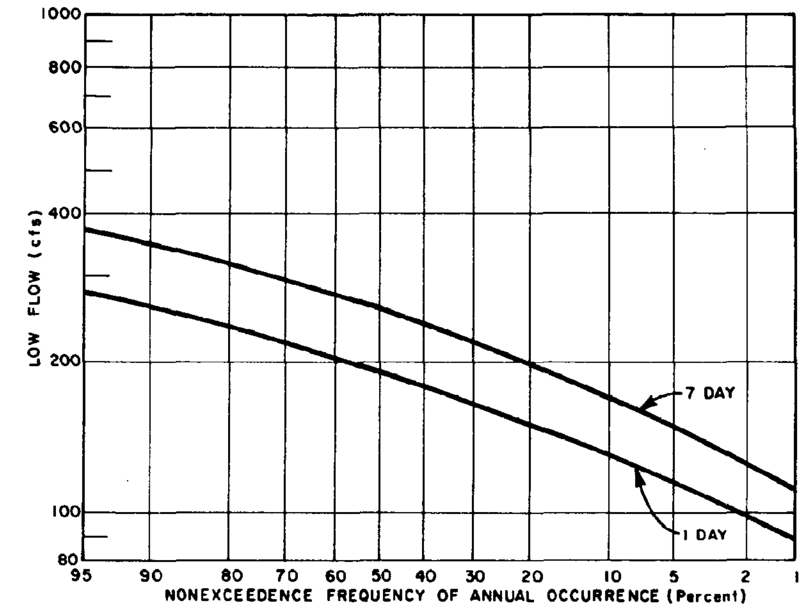


FIGURE 2–42 Low Flow Discharge Frequency Curves, Planning Subarea 3.2, Tittabawassee River at Midland, Mich. (2,400 Sq. Mi. Drainage Area)

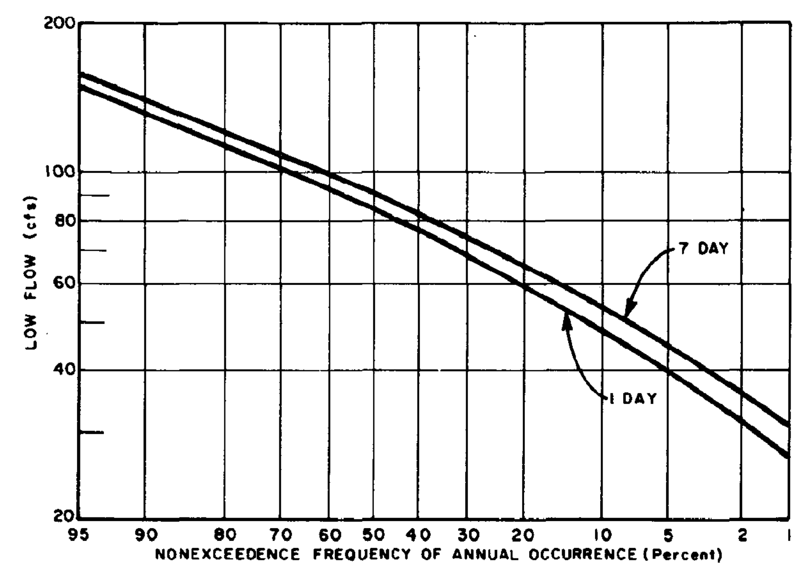


FIGURE 2–43 Low Flow Discharge Frequency Curves, Planning Subarea 4.1, Huron River Near Dexter, Mich. (506 Sq. Mi. Drainage Area)

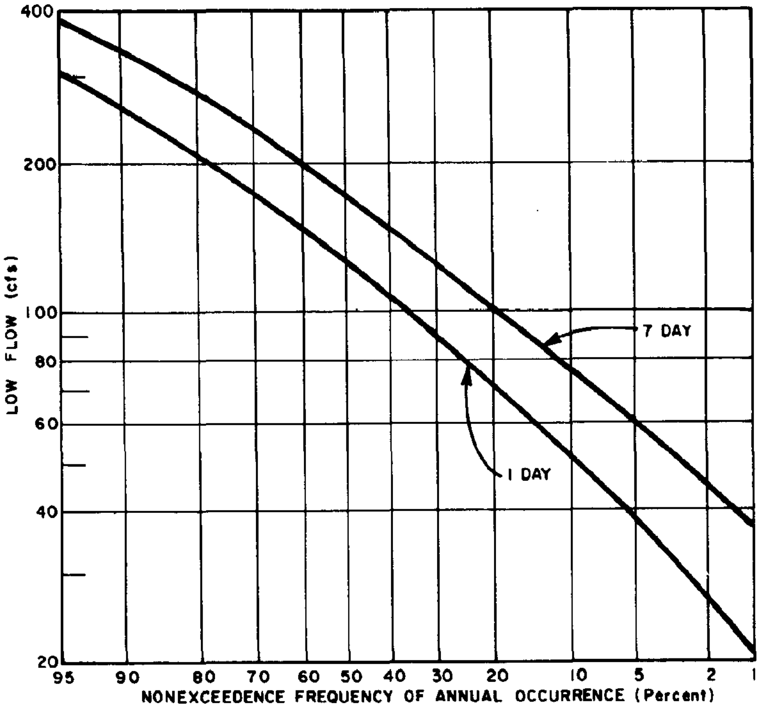


FIGURE 2–44 Low Flow Discharge Frequency Curves, Planning Subarea 4.2, Maumee River at Waterville, Ohio (6,329 Sq. Mi. Drainage Area)

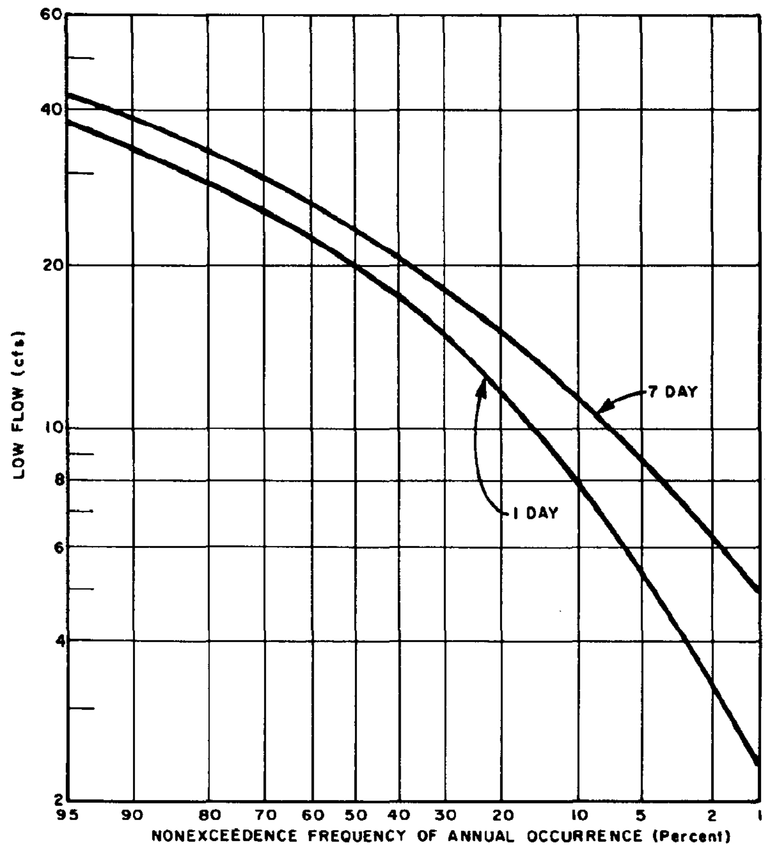


FIGURE 2–45 Low Flow Discharge Frequency Curves, Planning Subarea 4.3, Chagrin River at Willoughby, Ohio (246 Sq. Mi. Drainage Area)

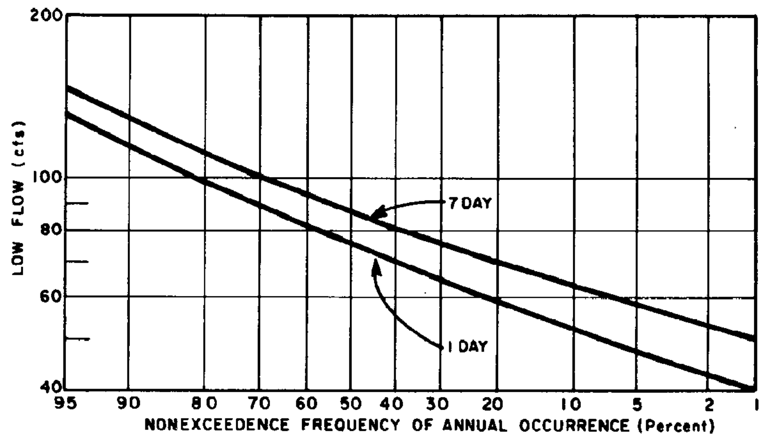


FIGURE 2–46 Low Flow Discharge Frequency Curves, Planning Subarea 4.4, Cattaraugus Creek at Gowanda, N.Y. (432 Sq. Mi. Drainage Area)

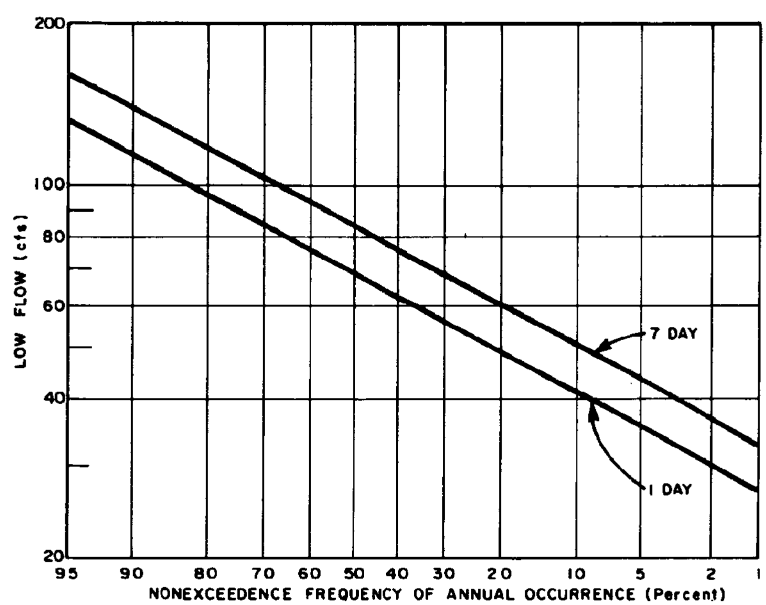


FIGURE 2–47 Low Flow Discharge Frequency Curves, Planning Subarea 5.1, Genesee River at Portageville, N.Y. (961 Sq. Mi. Drainage Area)

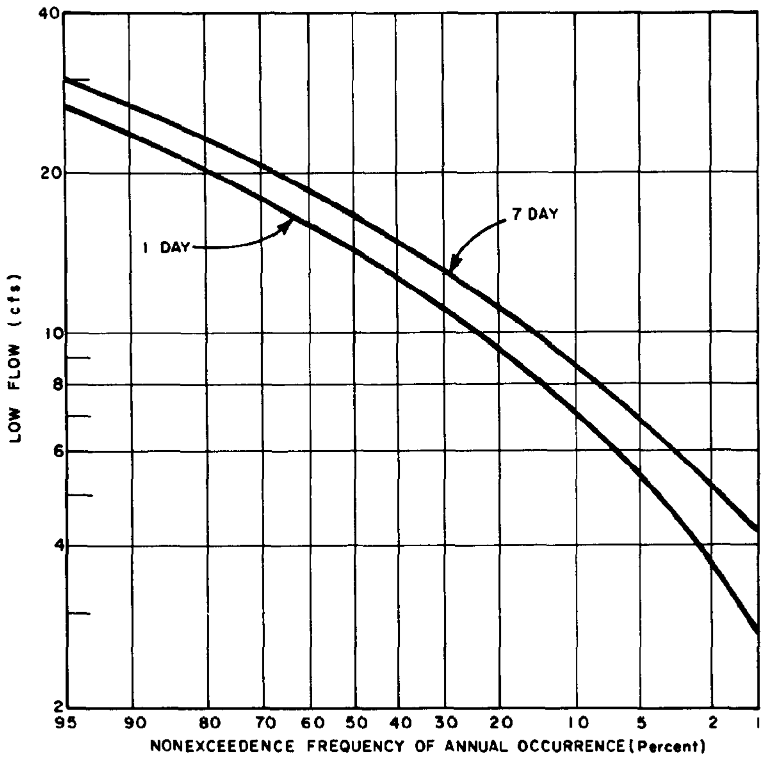


FIGURE 2–48 Low Flow Discharge Frequency Curves, Planning Subarea 5.2, Fall Creek Near Ithaca, N.Y. (126 Sq. Mi. Drainage Area)

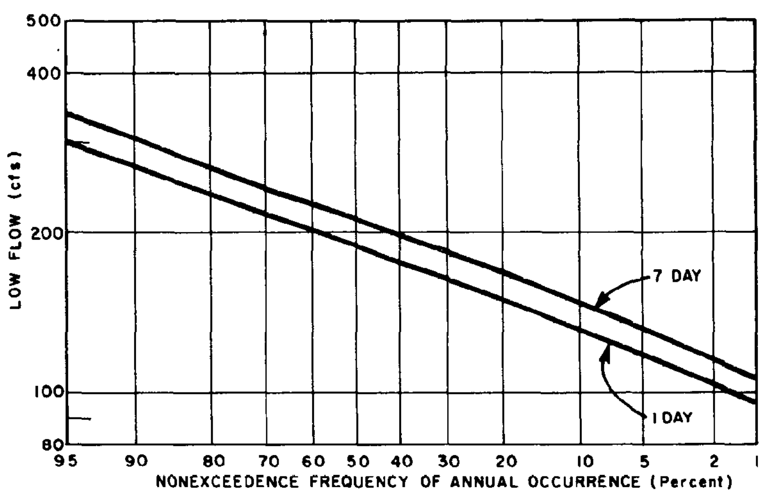


FIGURE 2–49 Low Flow Discharge Frequency Curves, Planning Subarea 5.3, St. Regis River at Brasher Center, N.Y. (616 Sq. Mi. Drainage Area)

Section 5

SURFACE WATER AVAILABILITY STUDIES

5.1 General

An evaluation of the total surface water availability of a river basin is fundamental to sound water resource planning. The limits to which a stream can supply or yield water must be known before that fixed minimum amount can be allocated or appropriated to the sometimes conflicting demands upon the water. The maximum yield a stream can produce is the average runoff over the period of record, assuming the period of record is representative. Average discharge values for selected hydrologic stations in each planning subarea are listed in Table 2–1. The maximum percentage of the average runoff that is practical to develop is related to the monthly, seasonal, and yearly variation in runoff; duration of drought or low-flow periods; evaporation and other losses from surface water runoff; diversion, size, and location of potential and existing storage sites; and the total volume of consumptive use. In general, streams with little variation in runoff over a period of time and large storage potential can be expected to furnish a yield approaching average runoff minus evaporation and other losses. However, streams with a large variation in runoff over a period of time and only very small storage potential can be expected to furnish yield only slightly greater than minimum base flow. This section develops a basic framework-scope methodology for estimating storage required to produce a sustained yield from an ungaged stream with a known drainage area.

5.2 Hydrologic Conversion Factors

The average discharge can be represented in cfs at the gaging location, cfs per square mile of contributing drainage area, inches of runoff per year over the drainage basin, acre-feet of runoff per year over the drainage basin, or acre-feet of runoff per square mile of drainage area depending upon the purpose for which the data will be used. Average annual discharge in cfs, shown in Table 2–1, can be converted to annual inches of runoff per square mile by dividing discharge by the drainage area and multiplying by 13.574. Annual runoff in acre-feet can be computed by multiplying average annual discharge in cfs by 724. Monthly mean discharge in cfs, shown in Tables 2–1 and 2–3, is converted to monthly inches of runoff per square mile by dividing discharge by drainage area and multiplying by 1.13. Monthly runoff in acre-feet is computed by multiplying monthly average discharge in cfs by 60.

5.3 Mass Curve-Storage Volumes

Many methods have been developed to determine surface water availability. One of the simplest procedures used to analyze recorded runoff is the mass curve analysis. This method generally produces results adequate for a framework study. The mass runoff curve is a plot on a time scale of the cumulative running total of mean monthly (or other duration) discharge for a continuous period of record. A specific slope of line on the mass curve represents a unique runoff, and the slope of the line connecting the two ends of the mass curve represents the average runoff for the period of record. One mass curve of runoff for a selected hydrologic station in each planning subarea is shown in Figures 2–50 through 2–64. Care was given to assure that the hydrologic station selected would be representative of conditions expected for all stations within the planning subarea. The maximum vertical distance between lines drawn parallel to the average runoff but tangential to the periodic and adjacent high and low points on the mass curve defines the volume of storage required to yield the average runoff continuously if evaporation and other losses are ignored. This same procedure can be used to determine the storage volume required to produce any yield less than average runoff by selecting the proper slope of the reference line segments. An example is shown in Figure 2–50.

A major drawback inherent in mass curve

analysis is that the results are associated with no statistical probabilities. Because nature never repeats itself exactly, a period of record is unique and the extreme low flows occurring during that particular period may or may not be rare events. The expected probabilities of recurrence of actual periods of extreme low flow would be information necessary for the proper assessment of an area's water resources. The Ohio Department of Natural Resources has published such an analysis of streamflow data collected in that State. The method and results are mentioned in Bulletins 37[4] and 40.[12] These amplify previous studies published as Bulletin 13.[5] The method used is similar to that developed by John B. Stall.[6]

5.4 Storage Yield Relationships for Selected Stations

Figures 2–65 through 2–79, developed from the mass curves, define the relationships between required storage per square mile of contributing drainage area and the percent of average runoff that the stream can yield if that amount of storage is furnished. However, the relationships do not include evaporation, transmission losses, or any other loss that may be unique to a basin. Required storage should be increased by the amounts of these losses. The data from Figures 2–65 through 2–79 can be used to determine storage requirements needed to furnish a given percentage of average runoff reported at hydrologic stations in each planning subarea shown in Table 2–1. When using the data, the hydrologic station being studied should be matched with the mass curve station developed for that planning subarea. Although it would be preferable to match a hydrologic station with mass curve data for a particular hydrologic area, a relatively high degree of confidence can be placed on the method developed for this appendix.

5.5 Sample Storage Requirement Calculation

Data in this appendix can be used to estimate the storage required to produce a sustained yield from an ungaged stream with known drainage area.

For example, at the site in question, it is decided to develop a sustained yield of 30 cfs. The site is in Planning Subarea 1.1 on the Temperance River, Minn., and has an upstream drainage area of 100 square miles.

From Figure 2–1 it is determined that hydrologic station 125 is the closest station geographically, and station 145 is the closest hydrologic station to the Temperance River having a storage yield relationship.

From Table 2–1, the assumed annual discharge would be 90 cfs, determined by dividing the average discharge for station 125 by its drainage area and then multiplying by the drainage area of the ungaged site, that is, (103/114) X 100 equals 90 cfs. The desired sustained yield of 30 cfs is 33 percent of the computed average discharge.

From Figure 2–65, the storage yield curve for station 145, a storage of 120 acre-feet per square mile is needed to produce a sustained yield of 33 percent of average discharge. Multiplying 120 by 100 square miles suggests that a total storage of 12,000 acre-feet, not including evaporation, transmission losses, and other losses, would be required to produce a sustained yield of 30 cfs at the site in question.

5.6 Streamflow Routing Characteristics

During a flood, duration, magnitude, and volume of the flow are usually modified by the physical characteristics of the stream. Mathematical expressions, procedures, or coefficients developed by an analysis of experienced-discharge hydrographs at selected intervals along the stream to define the time of travel and the change in hydrograph peaks, duration, shape, and volume are defined as the streamflow routing characteristics. Because the routing characteristics depend not only upon the physical characteristics of the stream but also on the magnitude of discharge, detailed design work requires that these characteristics be analyzed separately for each reach of stream being studied. However, this detail is beyond the scope of a framework report and is not included in this appendix for streams in the Great Lakes Basin. Several of the reports listed in the Bibliography include routing characteristics for specific areas, and these reports can be consulted for this information.

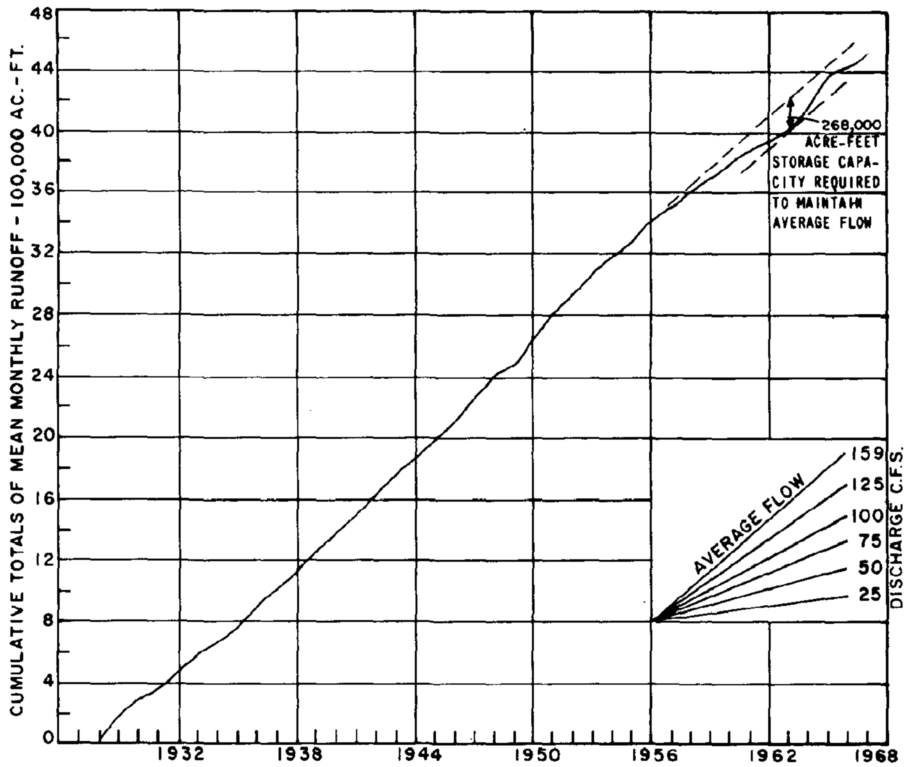


FIGURE 2–50 Mass Curve of Runoff, Planning Subarea 1.1, Baptism River at Beaver Bay, Minn.

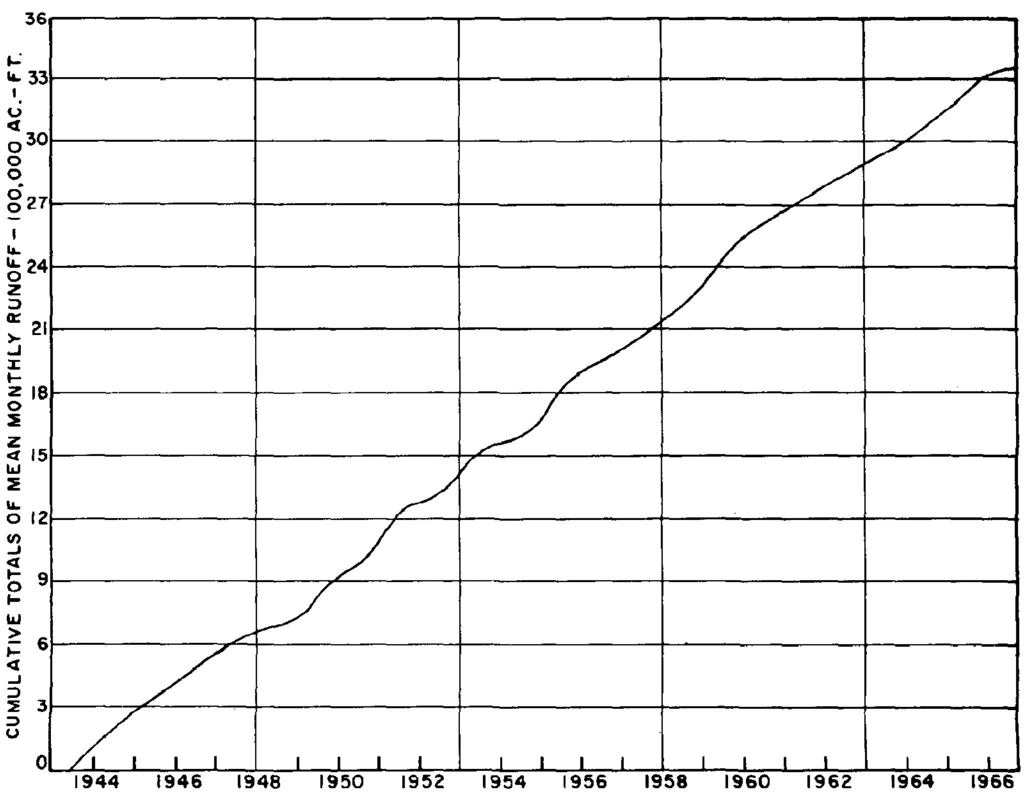


FIGURE 2–51 Mass Curve of Runoff, Planning Subarea 1.2, Sturgeon River Near Sidnaw, Mich.

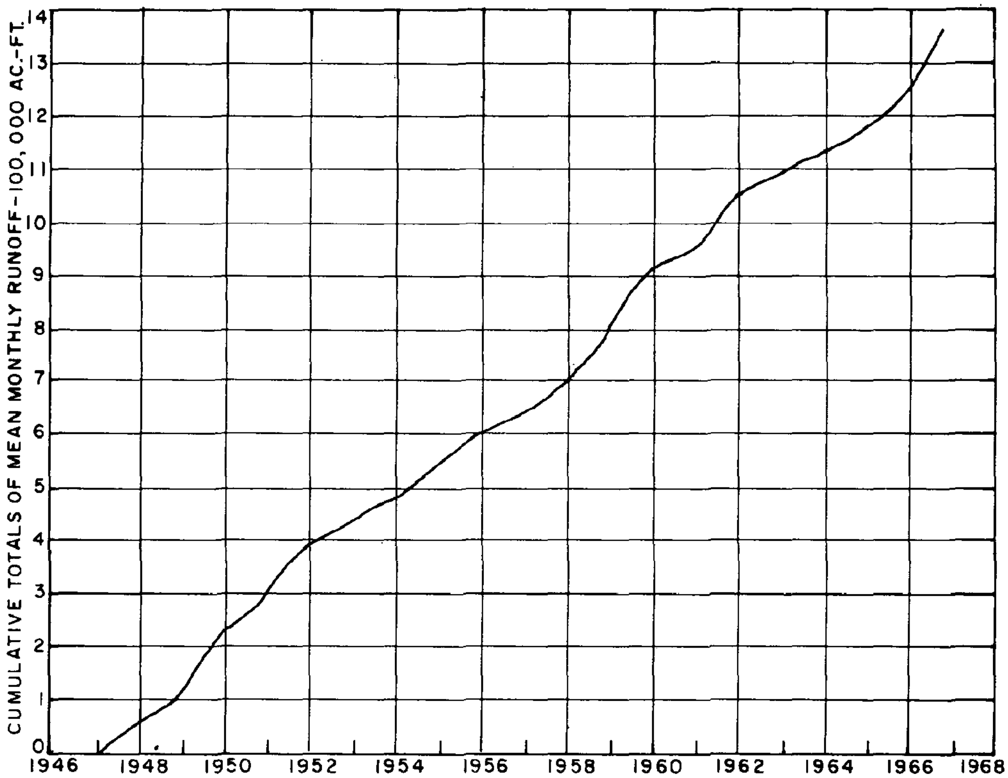


FIGURE 2–52 Mass Curve of Runoff, Planning Subarea 2.1, Pine River Powerplant, Wis.

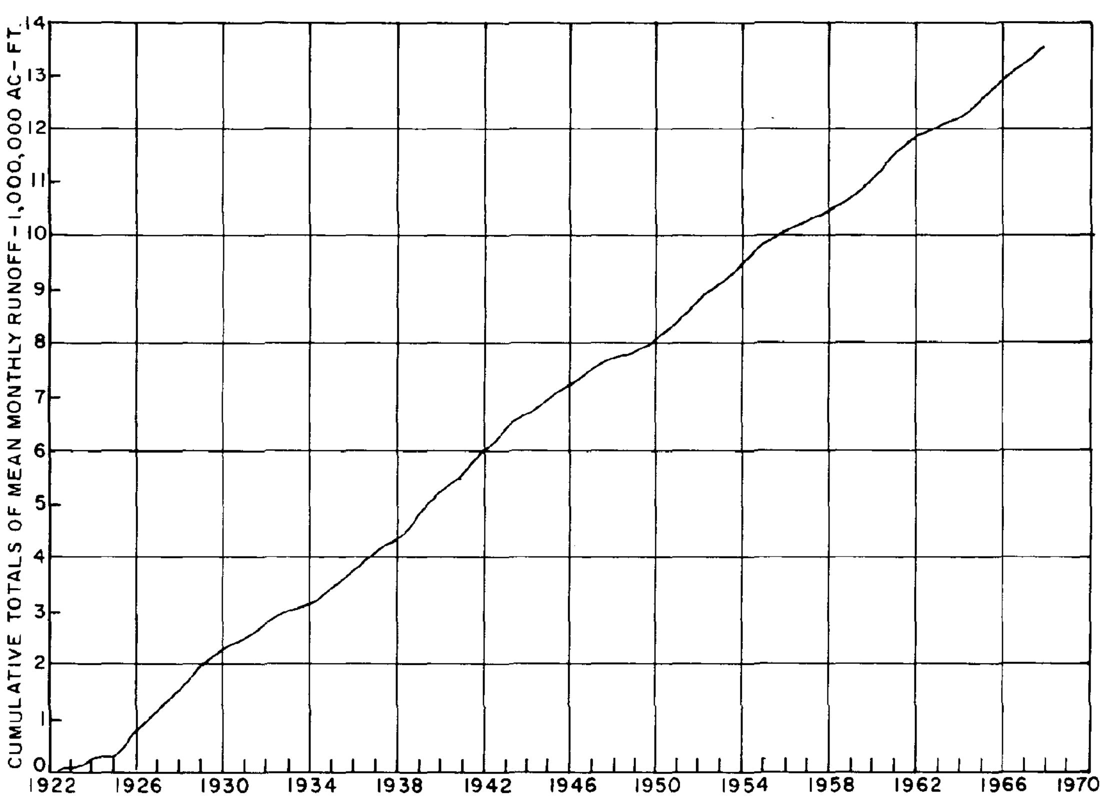


FIGURE 2–53 Mass Curve of Runoff, Planning Subarea 2.2, Deep River at Lake George Outlet at Hobart, Ind.

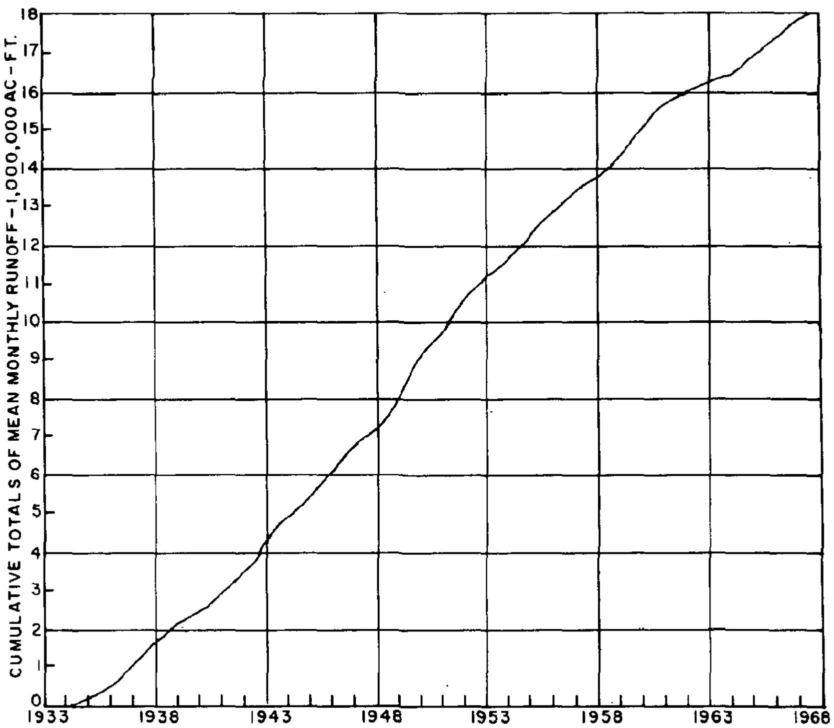


FIGURE 2–54 Mass Curve of Runoff, Planning Subarea 2.3, Grand River at Lansing, Mich.

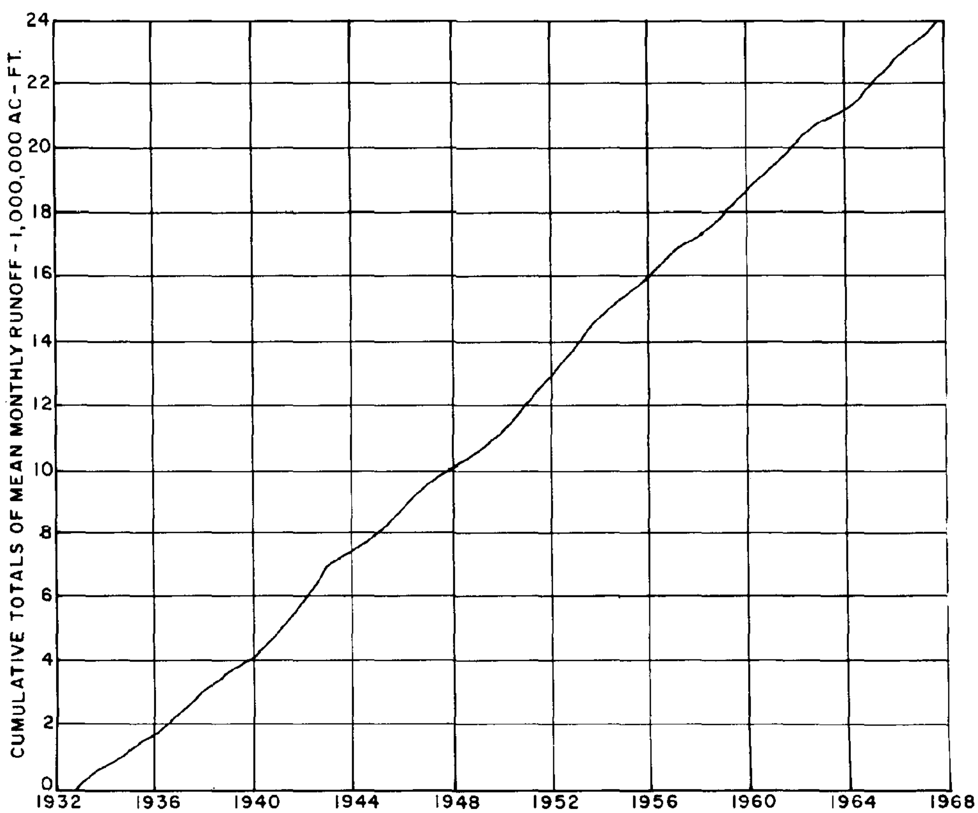


FIGURE 2–55 Mass Curve of Runoff, Planning Subarea 2.4, Muskegon River at Evart, Mich.

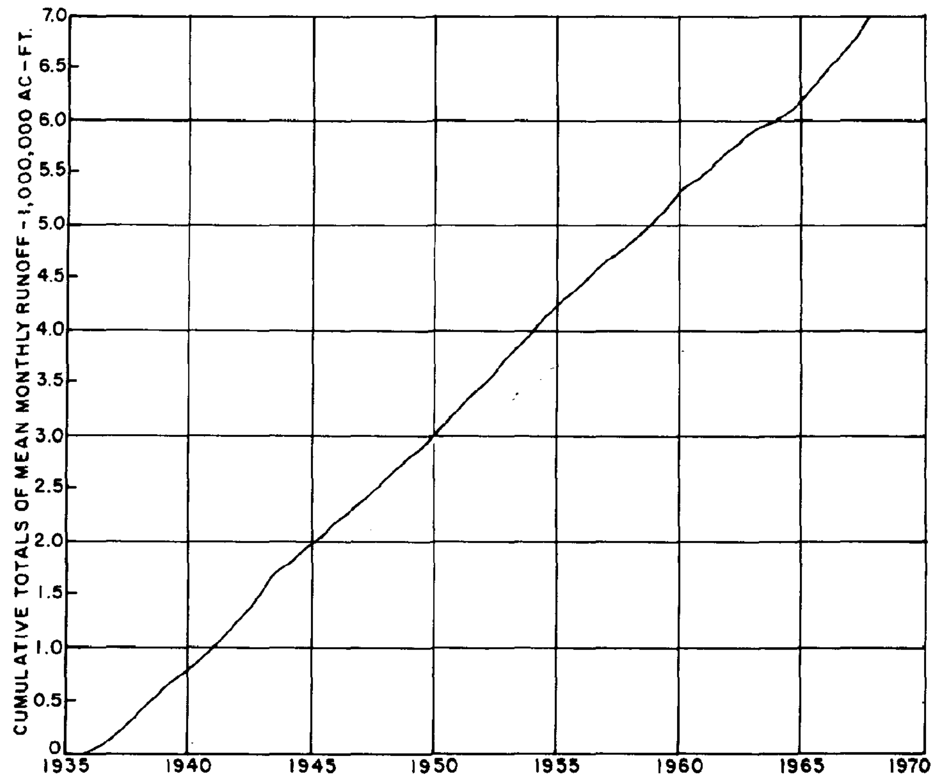


FIGURE 2–56 Mass Curve of Runoff, Planning Subarea 3.1, Rifle River at Sterling, Mich.

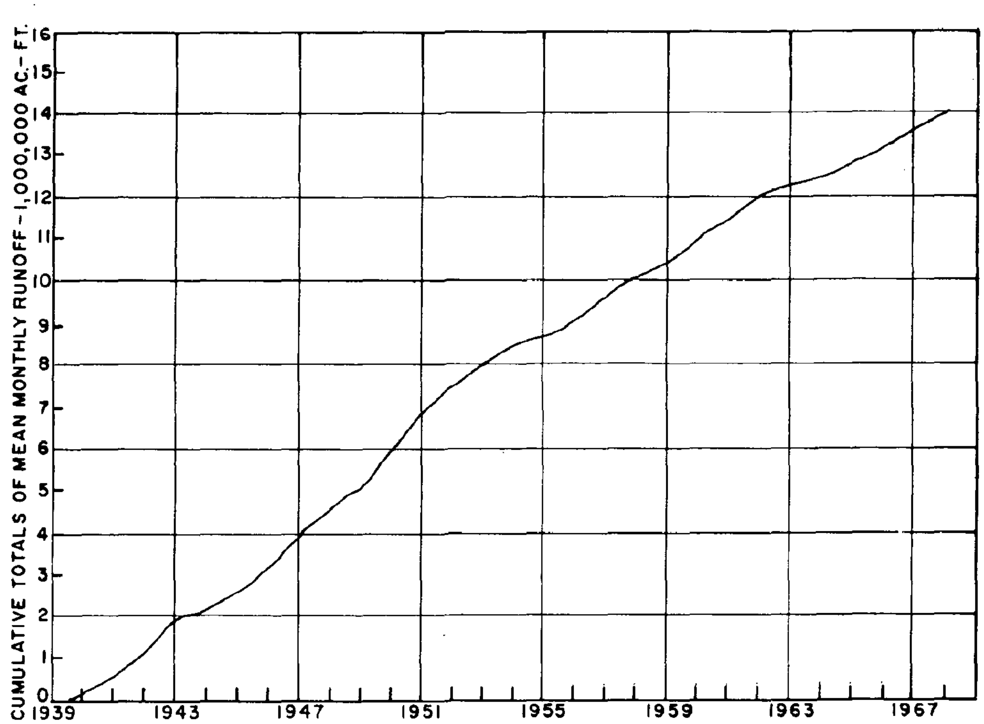


FIGURE 2–57 Mass Curve of Runoff, Planning Subarea 3.2, Flint River at Fosters, Mich.

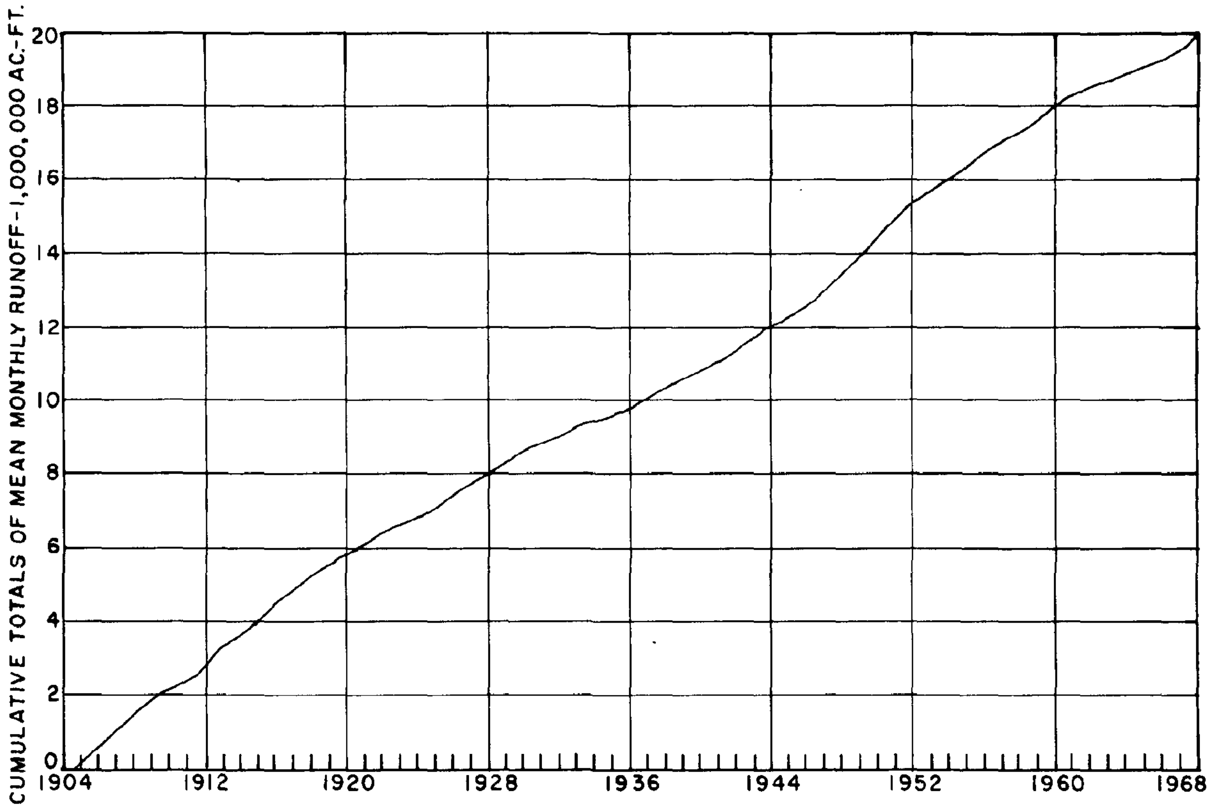


FIGURE 2–58 Mass Curve of Runoff, Planning Subarea 4.1, Huron River at Ann Arbor, Mich.

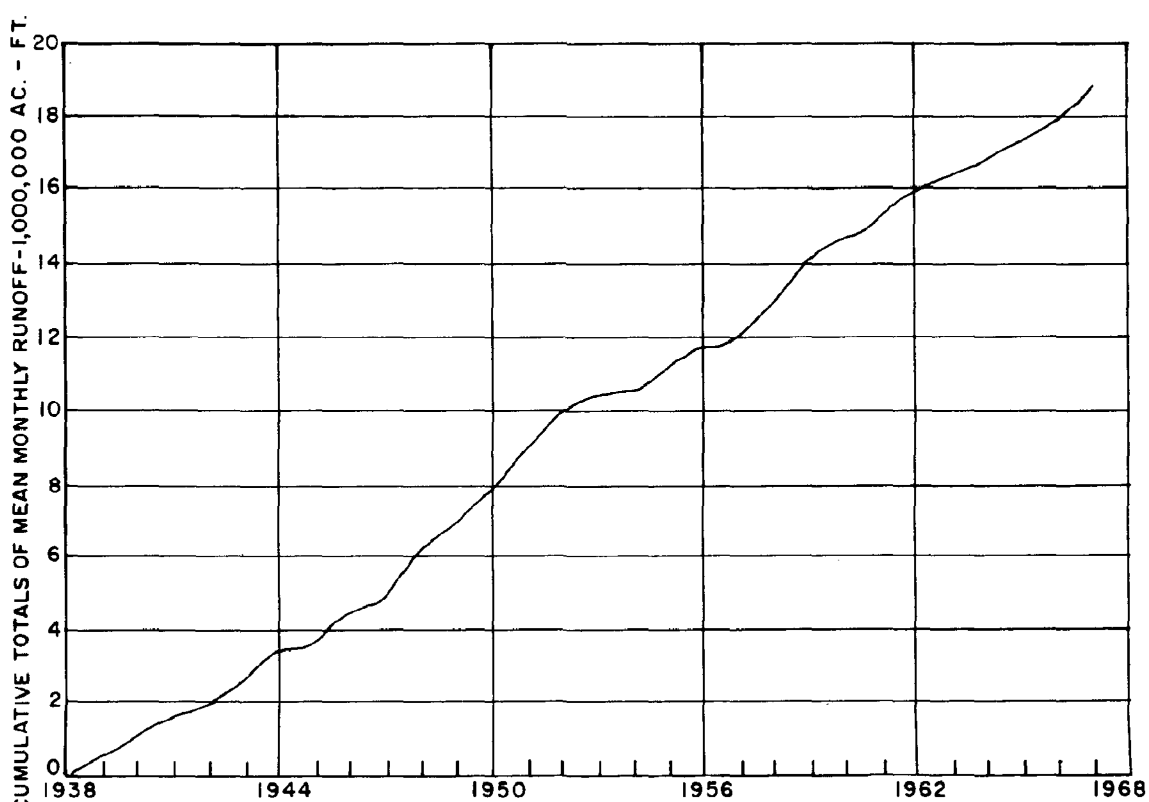


FIGURE 2–59 Mass Curve of Runoff, Planning Subarea 4.2, Sandusky River at Fremont, Ohio

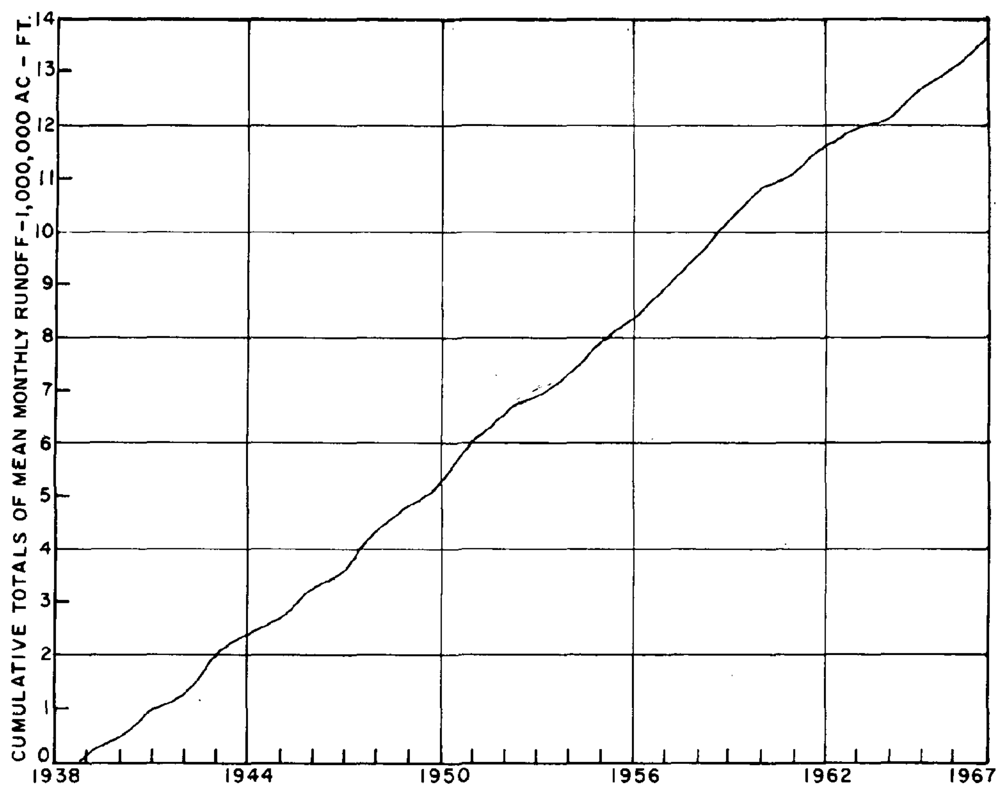


FIGURE 2–60 Mass Curve of Runoff, Planning Subarea 4.3, Grand River Near Madison, Ohio

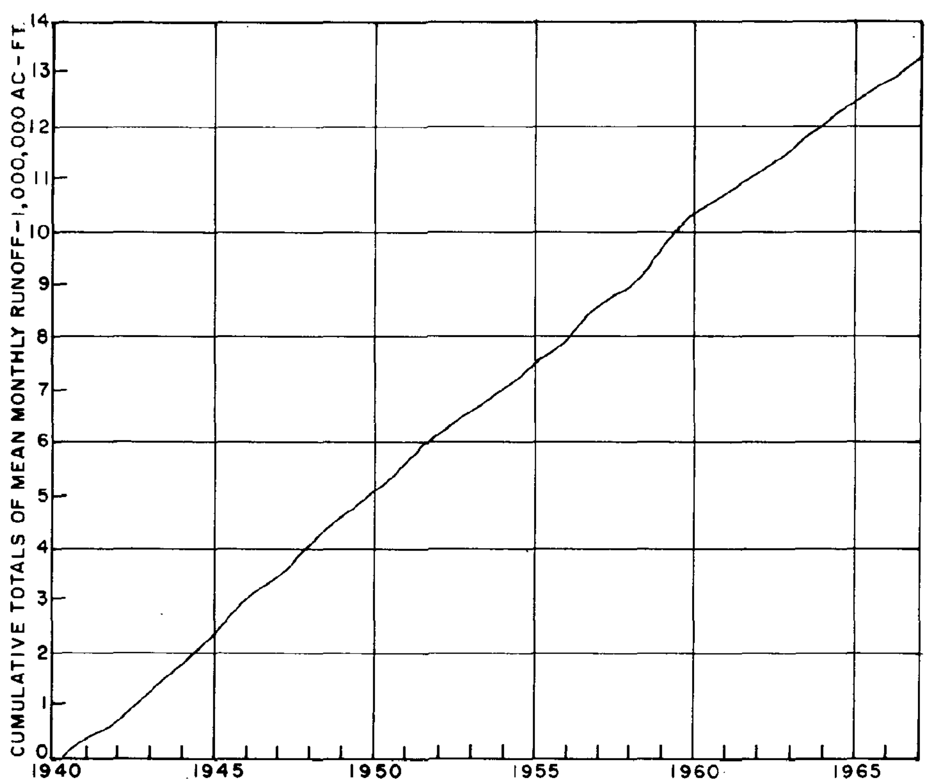


FIGURE 2–61 Mass Curve of Runoff, Planning Subarea 4.4, Cattaraugus Creek at Gowanda, N.Y.

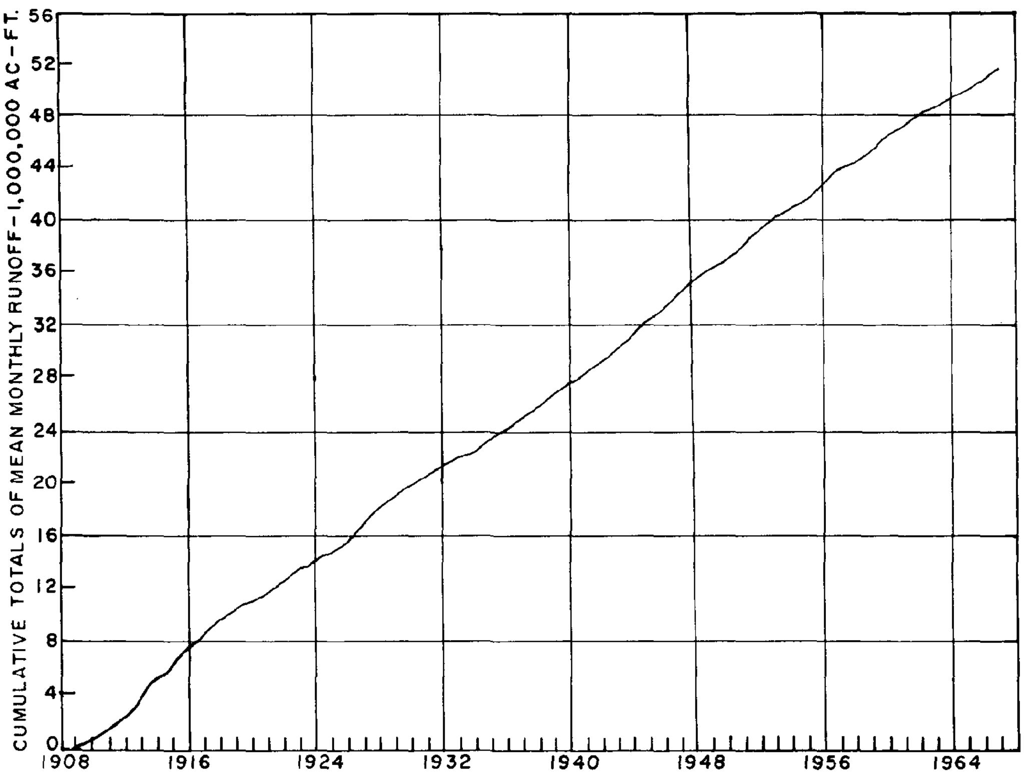


FIGURE 2–62 Mass Curve of Runoff, Planning Subarea 5.1, Genesee River at Portageville, N.Y.

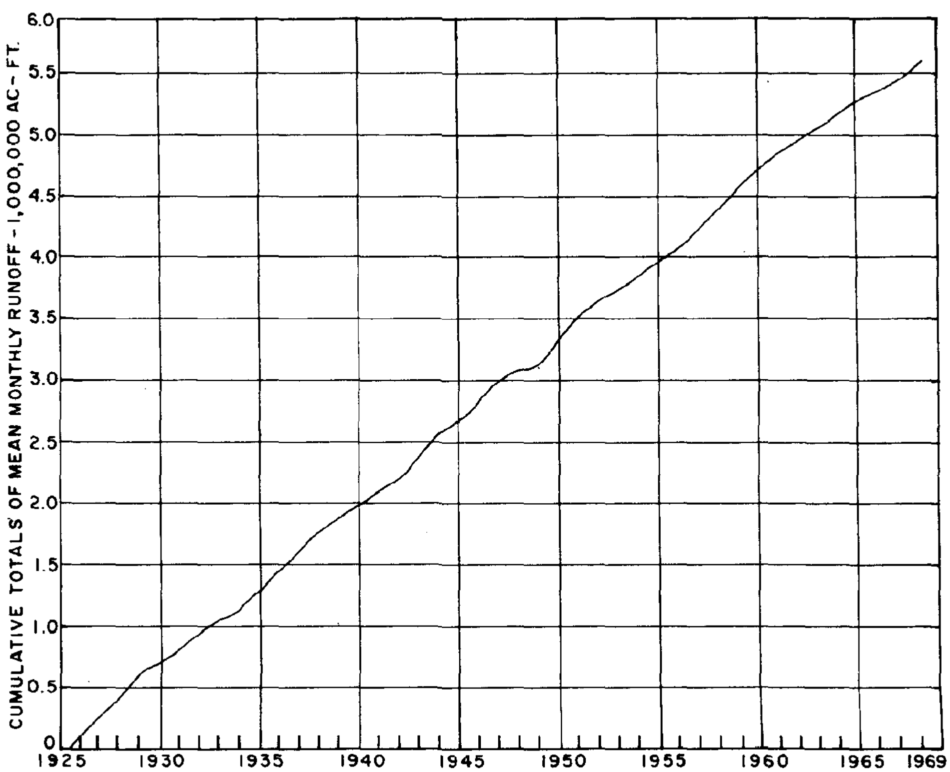


FIGURE 2–63 Mass Curve of Runoff, Planning Subarea 5.2, Fall Creek Near Ithaca, N.Y.

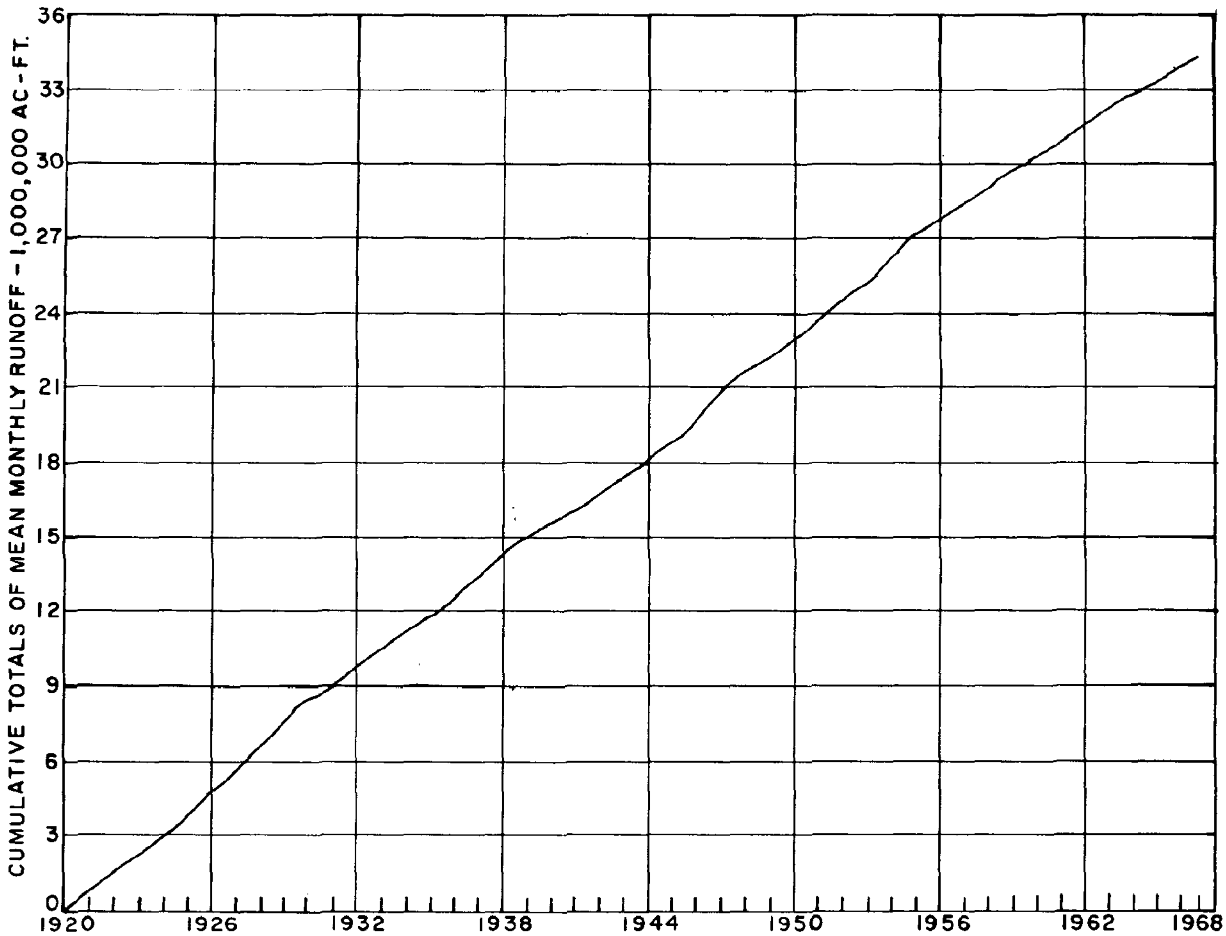


FIGURE 2–64 Mass Curve of Runoff, Planning Subarea 5.3, St. Regis River at Brasher Center, N.Y.

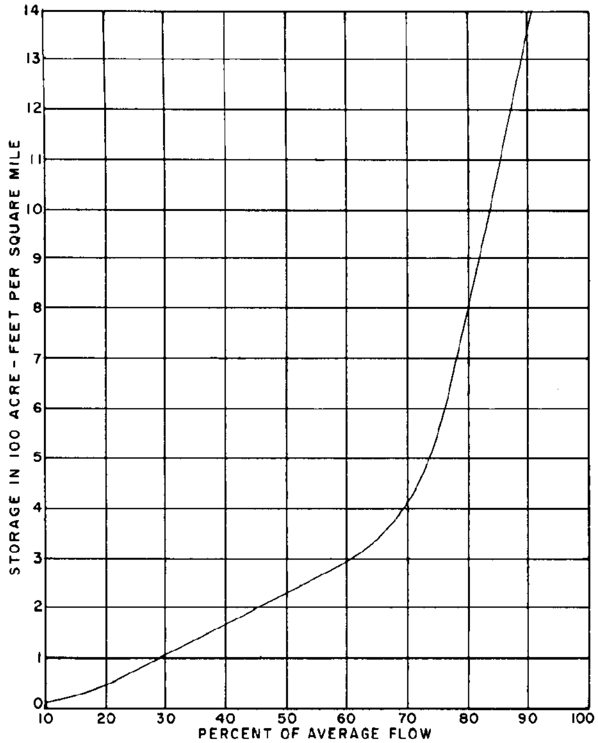


FIGURE 2–65 Generalized Storage Yield Relationship, Planning Subarea 1.1, Baptism River at Beaver Bay, Minn. (140 Sq. Mi. Drainage Area)

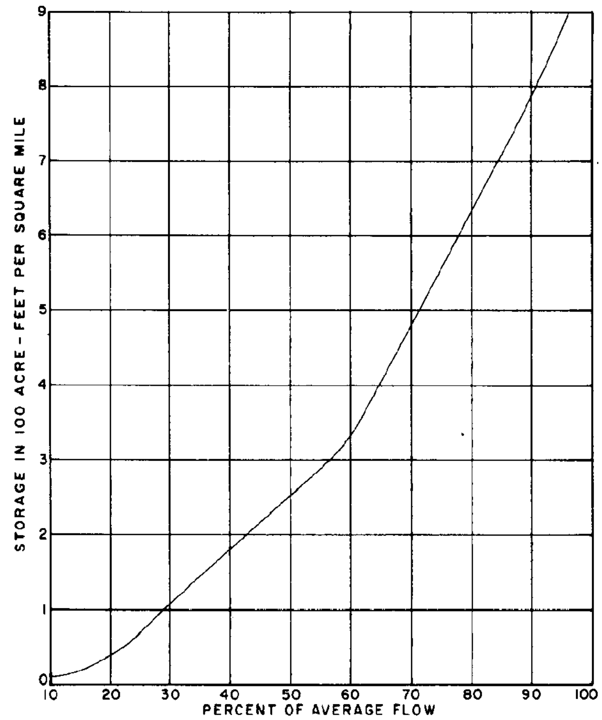


FIGURE 2–66 Generalized Storage Yield Relationship, Planning Subarea 1.2 Sturgeon River Near Sidnaw, Mich. (171 Sq. Mi. Drainage Area)

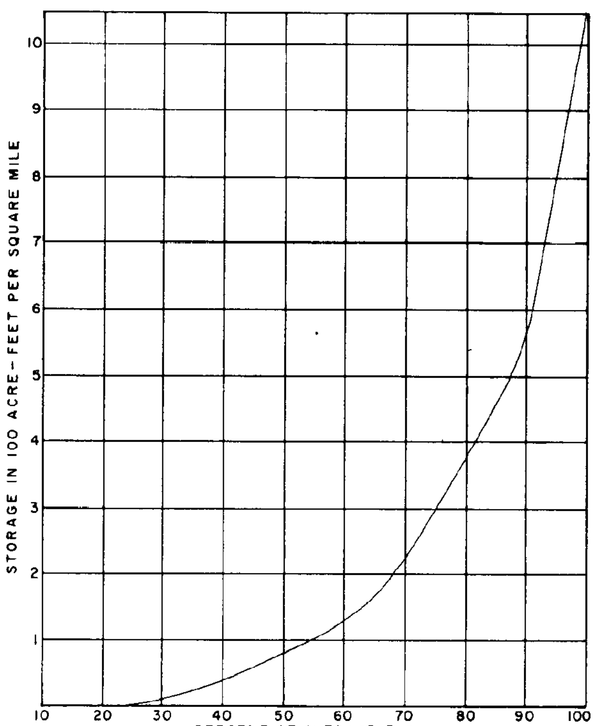


FIGURE 2–67 Generalized Storage Yield Relationship, Planning Subarea 2.1, Pine River at Pine River Powerplant, Wis. (528 Sq. Mi. Drainage Area)

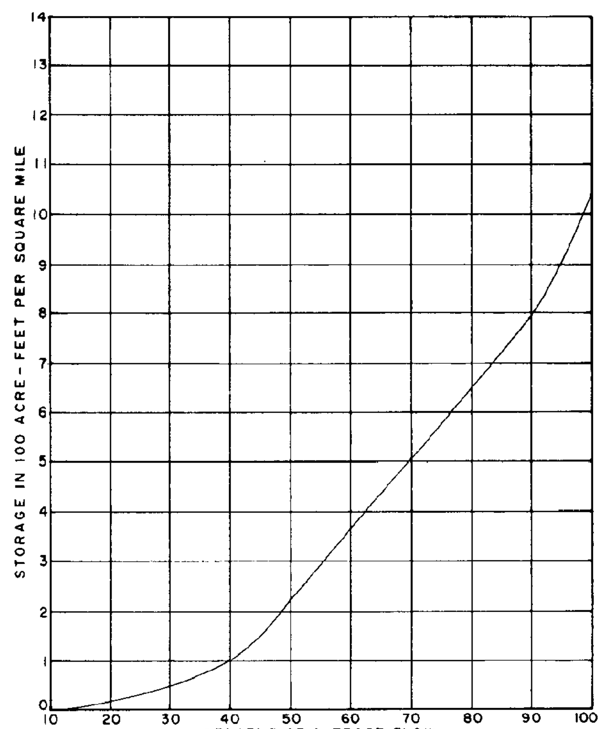


FIGURE 2–68 Generalized Storage Yield Relationship, Planning Subarea 2.2, Deep River at Lake George Outlet at Hobart, Ind. (125 Sq. Mi. Drainage Area)

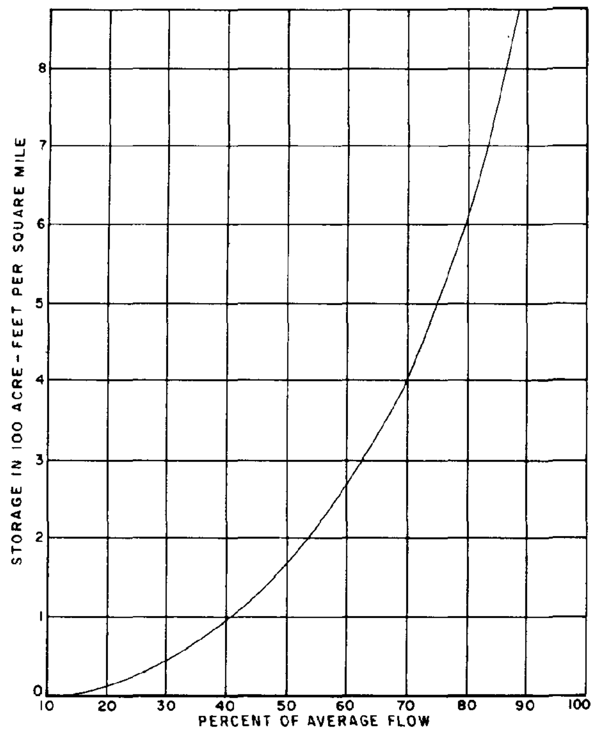


FIGURE 2-69 Generalized Storage Yield Relationship, Planning Subarea 2.3, Grand River at Lansing, Mich. (1,230 Sq. Mi. Drainage Area)

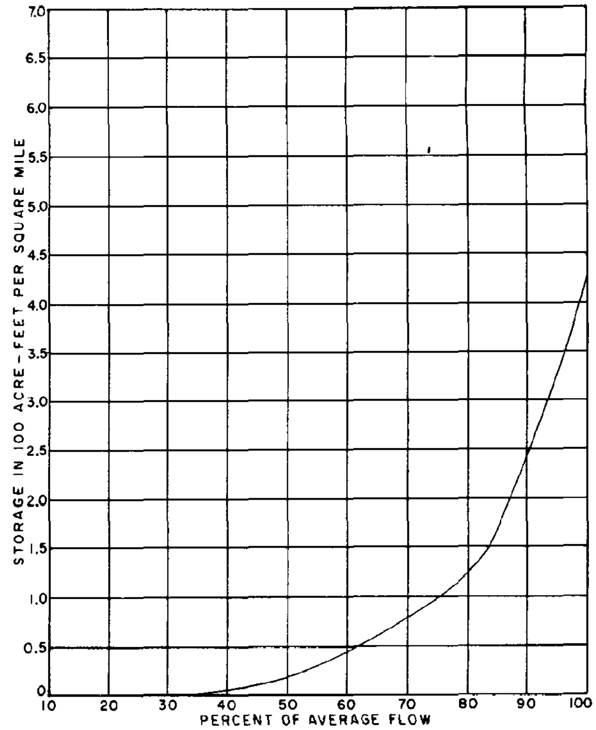


FIGURE 2-70 Generalized Storage Yield Relationship, Planning Subarea 2.4, Muskegon River at Evart, Mich. (1,450 Sq. Mi. Drainage Area)

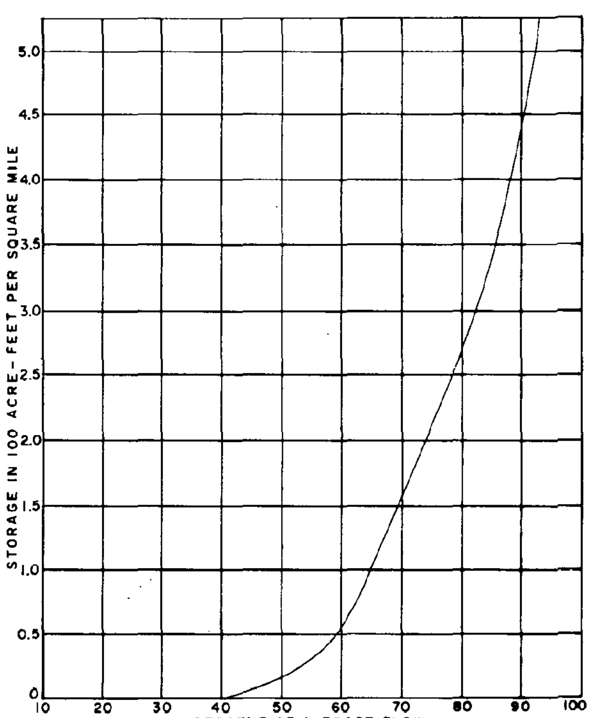


FIGURE 2-71 Generalized Storage Yield Relationship, Planning Subarea 3.1, Rifle River at Sterling, Mich. (320 Sq. Mi. Drainage Area)

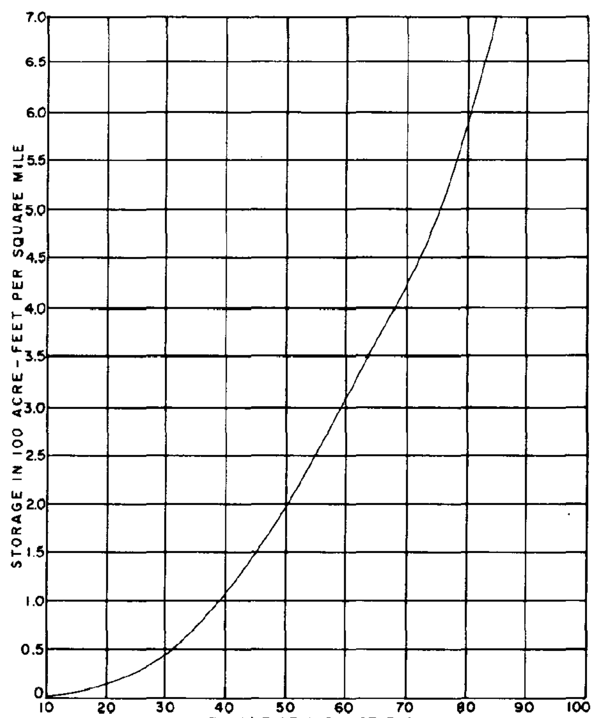


FIGURE 2-72 Generalized Storage Yield Relationship, Planning Subarea 3.2, Flint River at Fosters, Mich. (1,120 Sq. Mi. Drainage Area)

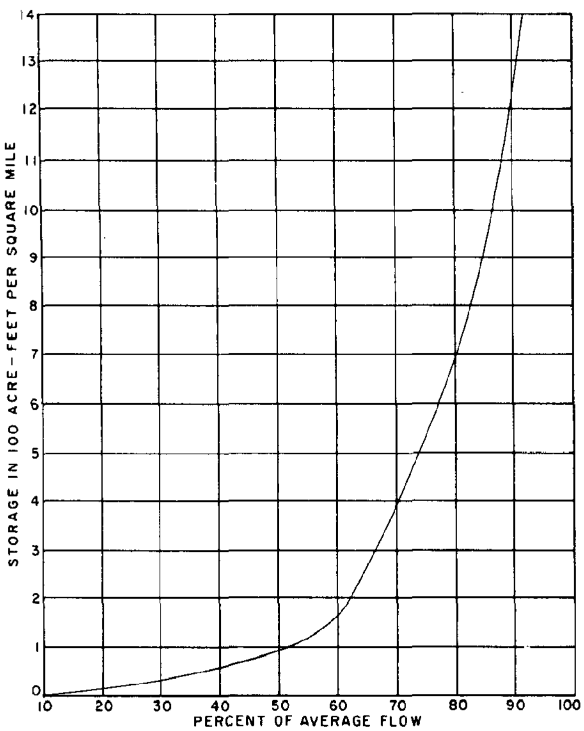


FIGURE 2–73 Generalized Storage Yield Relationship, Planning Subarea 4.1, Huron River at Ann Arbor, Mich. (711 Sq. Mi. Drainage Area)

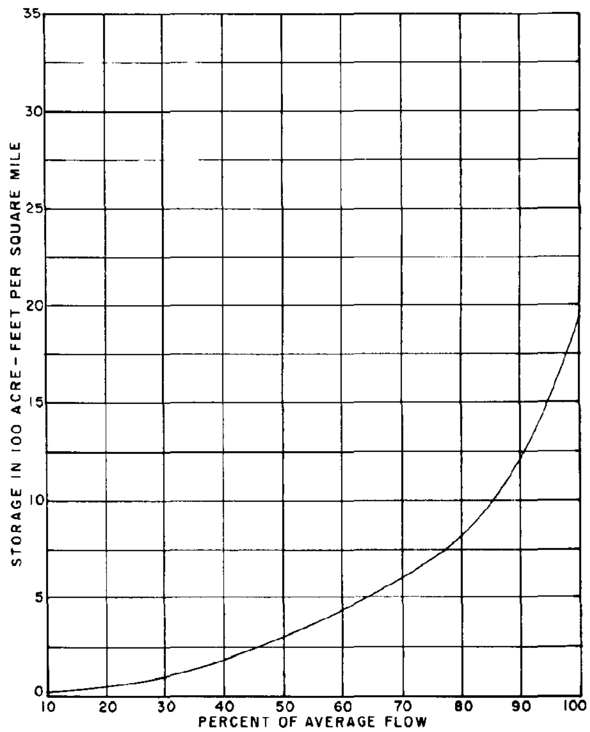


FIGURE 2–74 Generalized Storage Yield Relationship, Planning Subarea 4.2, Sandusky River at Fremont, Ohio (1,251 Sq. Mi. Drainage Area)

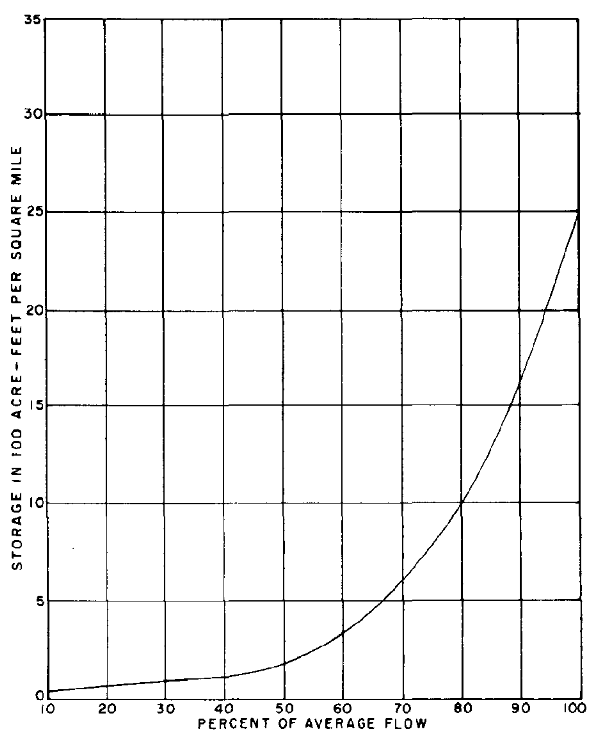


FIGURE 2–75 Generalized Storage Yield Relationship, Planning Subarea 4.3, Grand River Near Madison, Ohio (581 Sq. Mi. Drainage Area)

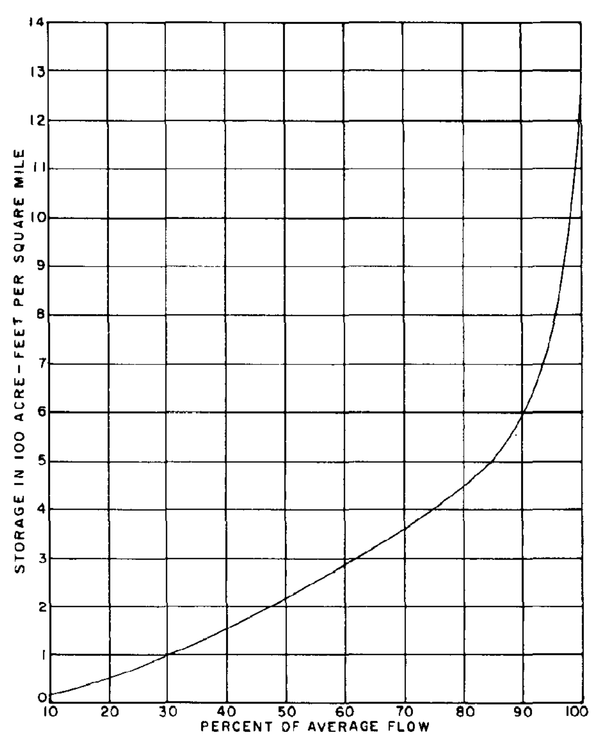


FIGURE 2–76 Generalized Storage Yield Relationship, Planning Subarea 4.4, Cattaraugus Creek at Gowanda, N.Y. (432 Sq. Mi. Drainage Area)

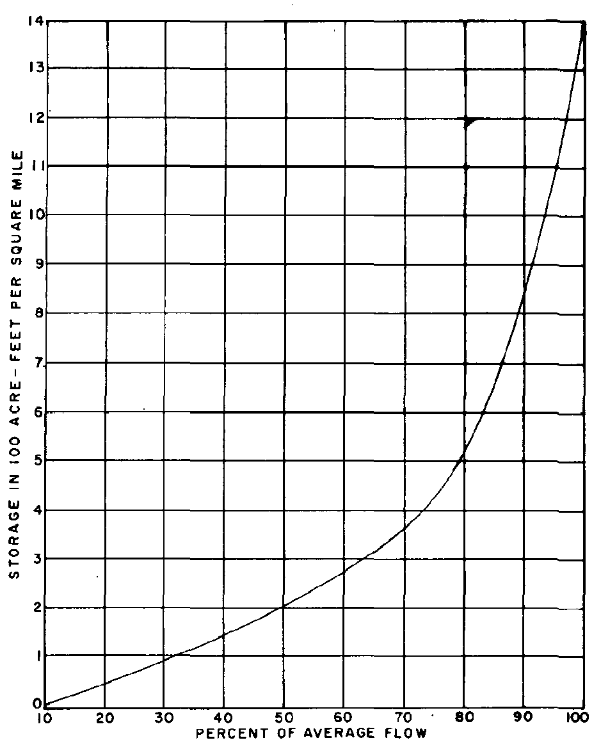


FIGURE 2-77 Generalized Storage Yield Relationship, Planning Subarea 5.1, Genesee River at Portageville, N.Y. (981 Sq. Mi. Drainage Area)

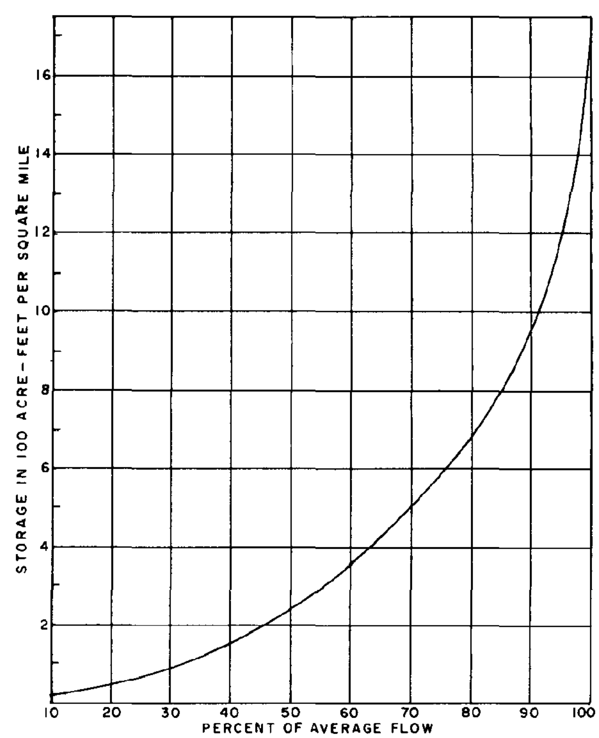


FIGURE 2-78 Generalized Storage Yield Relationship, Planning Subarea 5.2, Fall Creek Near Ithaca, N.Y. (126 Sq. Mi. Drainage Area)

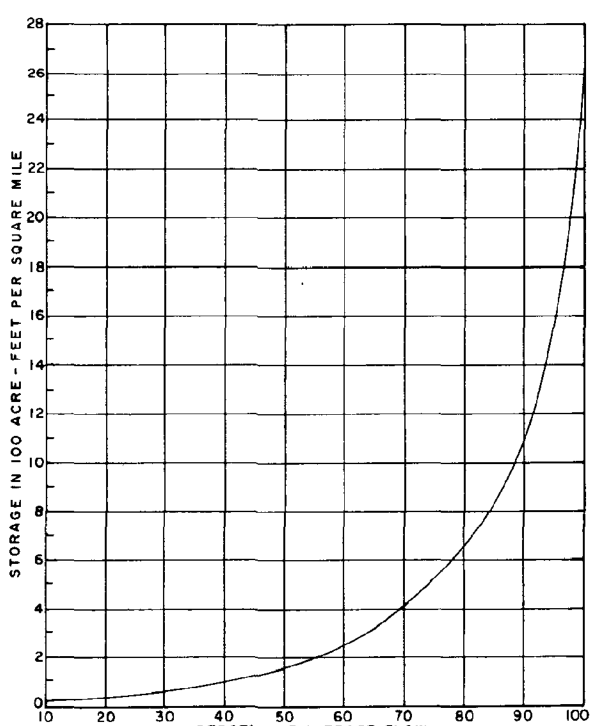


FIGURE 2-79 Generalized Storage Yield Relationship, Planning Subarea 5.3, St. Regis River at Brasher Center, N.Y. (616 Sq. Mi. Drainage Area)

Section 6

RESERVOIR SITES

6.1 General

In order to satisfy future water needs, it may be necessary in some cases to stabilize streamflows through reservoir control. To provide a base for analysis of this water management alternative, an inventory of existing and potential reservoir sites within the Basin was compiled and is listed in Table 2–5. Much of the data collected was provided from inventories already available from State and local agencies. In most cases, site data were evaluated from topographic maps and, wherever practical, verified by field reconnaissance. When analyzing the total storage potential for a specific site, allowances should be made for sedimentation in the reservoir, losses attributable to seepage and evaporation, and quality of reservoir inflows.

6.2 Existing and Potential Sites

In compiling the inventories, more than 2,500 existing and potential reservoir sites were analyzed. Because the smaller, low-capacity sites would have insignificant impact on framework-scope study results, only those sites having more than 500 acres of available surface area have been listed in Table 2–5 and shown in Figures 2–80 through 2–94. Included in Table 2–5 are data on site location, drainage area, pool area, and estimated storage capacity. Some of the data listed were obtained from inventories developed a number of years ago and may no longer be completely applicable when considering potential sites. Thus, before analyzing a specific reservoir site, the availability of the site should first be verified to see if any encroaching developments might have occurred. Also, many potential sites might have reservoirs that cross State boundaries. Planning studies for such reservoirs should include close coordination between the planning agencies of the States involved.

Data on sites with less than 500 acres surface area are included with working papers on file in the office of the Great Lakes Basin Commission. Table 2–6 is a listing by planning subarea of the number of existing and potential sites in the Great Lakes Basin not listed in Table 2–5.

6.3 Upground Storage Reservoirs

An upground storage reservoir is an earth structure designed to impound water. Unlike the more common on-stream reservoir, an upground storage reservoir is located off the main stream channel, so that water must be conveyed from the stream to it for storage. Usually this requires a river pump station and a pipeline to the reservoir unless it is possible to fill the reservoir by gravity flow through a canal from the stream.

Development of upground reservoirs is usually less economical than development and operation of on-stream facilities because of the high pumping costs. However, they do have advantages which may offset the direct economic shortcoming. Upground reservoirs can be constructed almost anywhere land is available. They have smaller overall land requirements, since they have uniform depth, no siltation problem, and flexibility in location so that disturbance of wildlife habitats, historical and aesthetic sites, and existing stream valley development can be minimized.

In northwest Ohio, an area of relatively flat topography, 21 communities in the area operate 40 upground storage reservoirs. The largest structure in this area is at Lima, Ohio, which has a pond area of 694 acres. Only four other sites are larger than 100 acres. Those range in pond area from 121 to 277 acres. Available information on potential upground reservoir sites in northwest Ohio indicates 36 locations that would provide an additional 7,755 acres of water surface area.

Two upground reservoirs, covering more than 800 acres each, are being constructed in Michigan. One is on the Lake Michigan shore near Ludington and the other is off the Tittabawassee River at Midland.

TABLE 2–5 Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Sec-tion	Dam Location Town-ship	Dam Location Range	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Superior West--Planning Subarea 1.1								
1 e	Beaver River	Minnesota		52N	15W	47	5,100	39,650
2 e	Beaver River	Minnesota		51N	14W	25	3,400	15,360
3 e	Cloquet River	Minnesota		52N	15W	546	9,900	171,500
4 e	Otter River	Minnesota		53N	15W	60	4,480	29,440
5 e	Whiteface River	Minnesota		56N	14W	130	6,800	81,920
6	St. Louis River	Minnesota	-	-	-	-	-	300,000
7	Baptism River	Minnesota	34	57N	7W	194	1,300	33,000
8	Poplar River	Minnesota	-	-	-	243	-	93,000
9	Cascade River	Minnesota	12	61N	2W	-	-	35,000
10	Brule River	Minnesota	-	-	-	-	-	62,000
11	Bad River	Wisconsin	-	47N	3W	570	-	44,000
Lake Superior East--Planning Subarea 1.2								
			Latitude		Longitude			
1 e	Au Train	Au Train, Mich.	46° 19'		86° 51'	80	1,950	12,300
2 e	Carp	Deer Lake, Mich.	46° 32'		87° 40'	36.3	1,700	22,500
3 e	Dead	Hoist, Mich.	46° 34'		87° 34'	141	4,236	55,300
4 e	Dead	Silver Creek, Mich.	46° 39'		87° 50'	24	-	26,800
5 e	Sturgeon	Prickett, Mich.	-		-	400	-	6,000
6 e	Ontonagon	Victoria, Mich.	-		-	650	-	45,700
7 e	South Br. Ontonagon	Cisco Lake Dam, Mich.	-		-	-	-	10,500
8 e	West Br. Ontonagon	Bergland Dam, Mich.	46° 35'		89° 33'	162	14,080	35,200
9 e	Middle Br. Ontonagon	Bond Falls, Mich.	-		-	190	-	32,400
10	Sturgeon	Tibbets Falls, Mich.	-		-	155	-	46,000
11	Sturgeon	Big Falls, Mich.	-		-	322	-	46,000
Lake Michigan Northwest--Planning Subarea 2.1								
			Sec-tion	Town-ship	Range			
1	Peshekee	Michigan	36	50N	31W	19	580	5,000
2	Peshekee	Michigan	8	49N	30W	23	640	9,000
3	Baraga Creek	Michigan	10	49N	30W	8.5	500	7,000
4	Peshekee	Michigan	2	48N	30W	46	1,200	23,000
5	Dislino Creek	Michigan	6	48N	29W	19.5	1,400	35,000
6	West Branch Peshekee	Michigan	3	48N	30W	55.5	1,300	18,000
7	Beaufort Lake	Michigan	21	48N	31W	20	820	1,600
8	Lake Michigamme	Michigan	9	47N	30W	193	4,200	8,400
9	Wolf	Dalles, Wis.	-	-	-	604	-	9,000
			Latitude		Longitude			
10 e	Michigamme	Peavy Falls, Mich.	45° 59'		88° 13'	710	3,160	34,000
11 e	Michigamme	Way Dam, Mich.	46° 10'		88° 14'	642	7,000	119,950
Lake Michigan Southwest--Planning Subarea 2.2								
	None							
Lake Michigan Southeast--Planning Subarea 2.3								
			Sec-tion	Town-ship	Range			
1	Upper Grand	Michigan	27	45N	1W	25.6	510	4,300
2	Lower Grand	Michigan	31	9N	15W	29.0	580	6,200
3	Lower Grand	Michigan	18	7N	14W	41.0	640	6,000

TABLE 2-5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Sec-tion	Town-ship	Range	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Michigan Southeast--Planning Subarea 2.3 (continued)								
4	Lower Grand	Michigan	-	7N	14W	35.0	710	9,300
5	Thornapple	Michigan	35	5N	9W	50.0	870	10,500
6	Thornapple	Michigan	6	4N	8W	26.0	940	19,500
7	Thornapple	Michigan	17	3N	9W	31.0	1,060	15,100
8	Thornapple	Michigan	31	3N	7W	32.0	1,900	2,500
9	Thornapple	Michigan	4	2N	6W	13.0	570	11,600
10	Middle Grand	Michigan	13	6N	8W	23.0	590	20,000
11	Middle Grand	Michigan	25	7N	6W	53.0	980	19,300
12	Red Cedar	Michigan	33	3N	1W	32.0	2,220	25,000
13	Upper Grand	Michigan	3	15N	3W	35.0	2,230	12,300
14	Red Cedar	Michigan	-	-	-	9.8	1,230	12,600
15	Doan Creek	Michigan	-	-	-	32.5	2,030	25,000
16	Doan Creek	Michigan	-	-	-	26.7	1,950	25,000
17	Deer Creek	Michigan	-	-	-	21.9	1,850	25,000
18	Maple	Michigan	-	-	-	10.1	500	3,000
19	Maple	Michigan	-	-	-	7.4	740	7,880
20	Sleepy Hollow	Michigan	-	-	-	11.1	546	8,210
21	Battesse Creek	Michigan	-	-	-	18.2	715	3,200
22	Battesse Creek	Michigan	-	-	-	21.7	1,120	7,370
23	Western Creek	Michigan	-	-	-	13.0	1,780	15,120
24	Indian Creek	Michigan	-	-	-	4.0	540	5,720
25	Otter Creek	Michigan	-	-	-	7.4	1,400	10,400
26	Upper Grand	Michigan	-	-	-	3.7	530	3,410
27	Columbia Creek	Michigan	-	-	-	14.8	980	11,700
28	Looking Glass	Michigan	-	-	-	9.8	530	3,670
29	Vermillion Creek	Michigan	-	-	-	49.9	1,400	10,805
30	Bad Creek	Michigan	-	-	-	20.1	1,380	12,340
31	Portage	Michigan	-	-	-	30.1	2,200	7,800
32	Butternut Drain	Michigan	-	-	-	15.6	650	3,420
33	Thornapple	Michigan	-	-	-	71.7	5,500	25,000
34	Little Thornapple	Michigan	-	-	-	23.5	1,690	18,080
35	Little Thornapple	Michigan	-	-	-	28.8	2,040	23,650
36	Lacy Creek	Michigan	-	-	-	11.2	1,150	14,090
37	Thornapple	Michigan	-	-	-	9.1	750	7,760
38	Thornapple	Michigan	-	-	-	15.9	540	7,490
39	Cedar Creek	Michigan	-	-	-	16.2	520	8,260
40	Cedar Creek	Michigan	-	-	-	25.3	800	13,720
41	Nash Creek	Michigan	-	-	-	12.5	1,100	22,010
42	Rogue	Michigan	-	-	-	9.2	680	17,570
43	Mill Creek	Michigan	-	-	-	10.7	520	5,400
44	Deer Creek	Michigan	-	-	-	25.8	1,360	21,880
45	Bass Creek	Michigan	-	-	-	29.1	970	7,850
46	Crockery Creek	Michigan	-	-	-	28.4	750	7,740
47	Rio Grande Creek	Michigan	-	-	-	11.0	580	6,470
48	Lower Grand	Michigan	-	-	-	4.8	600	5,750
49	Grand River	Michigan	20,21,29	7N	5W	1,777	3,100	56,000
50	Grand River	Michigan	8,17	5N	5W	1,418	5,500	158,000
51	Grand River	Michigan	20	5N	5W	1,400	3,600	105,000
52	Grand River	Michigan	27	5N	5W	1,382	1,920	37,500
53	Grand River	Michigan	35	4N	3W	856	5,780	63,700
54	Grand River	Michigan	15	3N	3W	846	1,800	14,500
55	Grand River	Michigan	32,33	1N	2W	569	27,600	221,300
56	Grand River	Michigan	9	1S	1W	409	19,300	109,300
57	Grand River	Michigan	26,35	3S	1W	53	1,200	6,900
58	Grand River	Michigan	33,34	4S	1W	10	520	7,500
59	Crockery Creek	Michigan	13,14	8N	15W	160	2,320	27,700
60	Crockery Creek	Michigan	28	9N	14W	110	1,070	19,700
61	Rogue	Michigan	25	9N	11W	231	5,310	78,300
62	Bear Creek	Michigan	30	8N	10W	27	720	16,400

TABLE 2-5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Sec-tion	Town-ship	Range	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Michigan Southeast--Planning Subarea 2.3 (continued)								
63	Thornapple	Michigan	21	5N	10W	798	7,000	115,000
64	Coldwater Creek	Michigan	36	5N	10W	192	3,370	68,400
65	Coldwater Creek	Michigan	6	4N	8W	80	2,180	24,200
66	Campbell Lake	Michigan	29,30	5N	9W	10	2,460	39,900
67	Thornapple	Michigan	32	4N	9W	525	550	5,700
68	Cedar Creek	Michigan	9	2N	8W	44	3,460	109,700
69	Unnamed Creek	Michigan	23	3N	8W	6	730	13,600
70	Highbank Creek	Michigan	31	3N	7W	32	3,480	4,630
71	Mud Creek	Michigan	9	3N	7W	53	1,260	15,700
72	Scipio Creek	Michigan	30	3N	6W	10	1,060	10,600
73	Thornapple	Michigan	27,34	3N	6W	190	4,600	42,500
74	Thornapple	Michigan	24	3N	6W	161	2,790	20,900
75	Thornapple	Michigan	29	3N	6W	190	7,350	87,600
76	Lacey Creek	Michigan	36	3N	6W	24	1,710	23,300
77	Flat	Michigan	13	7N	9W	578	2,020	51,600
78	Flat	Michigan	4	10N	8W	50	1,920	9,600
79	Prairie Creek	Michigan	16	7N	6W	100	1,820	61,900
80	Stony Creek	Michigan	26	7N	4W	139	4,890	48,950
81	Maple	Michigan	9	7N	5W	766	11,220	89,000
82	Fish	Michigan	24	8N	5W	161	1,220	35,600
83	Fish	Michigan	35,36	9N	5W	141	2,870	97,000
84	Pine Creek	Michigan	31,32	9N	3W	82	2,170	47,490
85	Maple	Michigan	10,11	8N	1W	205	8,210	61,000
86	Dickerson Creek	Michigan	1	8N	8W	101	990	14,900
87	Looking Glass	Michigan	34	6N	5W	312	3,230	36,700
88	Looking Glass	Michigan	1	5N	5W	310	3,350	35,970
89	Looking Glass	Michigan	15	5N	3W	262	1,330	10,910
90	Looking Glass	Michigan	4	5N	1E	161	2,110	11,500
91	Sycamore Creek	Michigan	2,11	3N	2W	102	1,300	14,000
92	Mud Creek	Michigan	33	3N	1W	32	3,160	31,650
93	Red Cedar	Michigan	27	4N	1W	306	2,040	23,800
94	Red Cedar	Michigan	5	3N	2E	228	6,610	67,200
95	Doan	Michigan	17,18	3N	2E	33	2,610	38,900
96	Spring Brook	Michigan	22,23	1S	3W	18	2,200	19,100
97	Sandstone Creek	Michigan	28	1S	3W	89	7,460	115,120
98	Portage	Michigan	3	2S	1E	159	10,440	20,880
99	Thornapple	Michigan	10	5N	10W	803	2,690	41,400
100	Quaker Brook	Michigan	1	2N	7W	17	660	7,240
101	Hayworth Creek	Michigan	18	8N	3W	50	920	14,300
102	Little Maple	Michigan	34	7N	1W	12	1,530	18,800
103	Alder Creek	Michigan	1	6N	1W	6	910	14,200
104	Buck Creek	Michigan	22	6N	12W	44	560	5,940
105	Glass Creek	Michigan	20	3N	9W	31	1,610	29,720
106	Spring Brook	Michigan	10,11	6N	2E	9	1,020	14,400
107	Grand River	Michigan	2	1N	3W	652	3,900	44,000
108	Sand Creek	Michigan	27	7N	13W	41	1,470	29,600
109	Plaster Creek	Michigan	17	6N	11W	44	2,750	64,600
110	Dickerson Creek	Michigan	15	9N	7W	96	1,090	19,000
111 e	Grand River	Michigan	-	-	-	4,883	600	-
112 e	Grand River	Michigan	33	7N	5W	1,751	660	-
113	Augusta Creek	Michigan	-	-	-	21	33,000	90,000
114	Wanadoga Creek	Michigan	-	-	-	44	4,800	80,000
115	Wanadoga Creek	Michigan	-	-	-	-	820	6,000
116	Rice Creek	Michigan	-	-	-	91	10,000	90,000
117	Rice Creek	Michigan	-	-	-	-	2,000	13,000
118	Rice Creek	Michigan	-	-	-	-	700	3,000
			Latitude		Longitude			
119 e	Kalamazoo	Morrow Lake	42° 17'		85° 29'	1,000	1,000	6,000
120 e	Kalamazoo	Lake Allegan	42° 34'		85° 57'	1,540	1,600	17,200

TABLE 2–5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Sec-tion	Town-ship	Range	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Michigan Southeast Planning Subarea 2.3 (continued)								
121	St. Joseph	Michigan	21	5S	18W	3,900	5,000	126,000
122	Paw Paw	Michigan	11,12	3S	16W	300	2,400	16,400
123	Rocky	Michigan	23	5S	12W	70	1,750	12,200
124	Rocky	Michigan	24	5S	12W	70	780	6,500
125	Rocky	Michigan	25	5S	12W	135	1,100	7,700
126	Nottawa Creek	Michigan	20,29	5S	9W	180	520	3,200
127	Nottawa Creek	Michigan	1	5S	8W	160	3,000	19,000
128	Nottawa Creek	Michigan	29	4S	8W	150	3,800	36,800
129	Coldwater	Michigan	9,10	5S	7W	290	570	7,800
130	Dowagiac Creek	Michigan	12	7S	17W	255	600	3,000
131	Dowagiac Creek	Michigan	30	6S	16W	255	1,040	9,100
132	Brush Creek	Michigan	22	3S	15W	34	1,030	18,000
133	Fawn	Indiana	17	38N	10E	160	1,800	11,200
134	Fawn	Michigan	16	8S	9W	140	2,540	26,000
135	Bango Creek	Indiana	26	37N	4E	70	3,100	36,500
136	St. Joseph	Indiana	28	38N	6E	2,840	1,850	7,000
137	White Pigeon	Michigan	10,11	8S	12W	210	560	4,100
138	Pipestone Creek	Michigan	3	5S	18W	58	920	17,450
139	Mill Creek	Michigan	26	3S	17W	28	600	6,400
140	East Branch Paw Paw	Michigan	17	3S	13W	46	1,165	17,900
141	Hog Creek	Michigan	28	5S	5W	67	2,500	22,000
142	Beebe Creek	Michigan	14	6S	3W	40	2,000	26,400
143	Pine Creek	Indiana	18	37N	6E	31	790	9,483
144	Turkey Creek	Indiana	33	36N	6E	183	920	5,500
145	St. Joseph	Michigan	30	5S	9W	800	3,700	36,000
146	St. Joseph	Michigan	34	5S	9W	611	4,200	50,000
147	St. Joseph	Indiana	14	38N	6E	2,693	3,600	18,000
148	Little Elkhart	Indiana	27,28,33	38N	7E	110	740	6,900
149	Pigeon	Indiana	29	38N	9E	373	540	3,000
150	Elkhart	Indiana	14	37N	5E	657	1,000	8,000
151	Prairie	Indiana	28	6S	10W	180	12,400	14,000
152	Beebe Creek	Indiana	13	6S	3W	44	1,350	11,600
153	Swan Creek	Indiana	35	6S	8W	52	1,510	3,760
154	Prairie	Indiana	31	6S	11W	56	860	4,300
155	Prairie	Indiana	28	6S	1W	127	1,230	4,900
156	Rocky	Indiana	25	5S	12W	115	2,340	18,450
157	Nottawa Creek	Indiana	1	5S	9W	159	3,080	22,260
158	St. Joseph	Indiana	1	6S	9W	514	850	3,840
159	Fawn	Indiana	9	8S	11W	73	1,290	7,470
160	Flowerfield	Michigan	4	4S	12W	20	1,420	9,840
161	St. Joseph	Michigan	33	4S	7W	217	1,480	15,840
162	St. Joseph	Michigan	25	4S	5W	156	2,640	16,460
163	Pokagon	Michigan	1,2	7S	16W	22	620	8,600
164	St. Joseph	Michigan	1	5S	19W	4,170	4,610	33,100
165	Paw Paw	Michigan	23	3S	18W	393	1,290	18,600
Lake Michigan Northeast Planning Subarea 2.4								
1	Middle Br. Escanaba	Michigan	21	48N	29W	16.5	1,100	26,000
2	Middle Br. Escanaba	Michigan	16	46N	27W	170	580	8,300
3	Green Creek	Michigan	24	46N	27W	8	530	11,000
4	Middle Br. Escanaba	Michigan	7	45N	25W	230	550	16,000
5	Goose Lake	Michigan	24	47N	26W	14.6	520	2,000
6	East Br. Escanaba	Michigan	4	45N	25W	112	600	7,000
7 e	Manistee	Michigan	31	22N	13W	1,451	1,540	-
8 e	Muskegon	Michigan	11	14N	10W	-	610	-
9 e	Muskegon	Michigan	18	12N	11W	2,224	1,380	-
10 e	Penoyer Creek	Michigan	18	12N	12W	-	3,970	-
11 e	Manistee	Michigan	30	23N	12W	1,018	2,025	-

TABLE 2-5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Sec-tion	Town-ship	Range	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
			Latitude		Longitude			
Lake Huron North Planning Subarea 3.1								
1 e	Au Sable	Alcona Pond, Mich.	44° 34'		83° 48'	1,469	1,075	-
2 e	Au Sable	Cooke Dam, Mich.	44° 28'		83° 34'	1,641	1,800	-
3 e	Upper So. Br. Thunder Bay	Fletcher Pond, Mich.	45° 02'		83° 47'	171	8,500	40,100
4 e	Au Sable	Foote Basin, Mich.	44° 26'		83° 26'	1,664	1,850	-
5 e	Lower So. Br. Thunder Bay	Hubbard Lake, Mich.	44° 52'		83° 36'	146	8,800	30,000
6	Thunder Bay	Norway Point, Mich.	45° 06'		83° 31'	1,260	1,700	6,000
			Sec-tion	Town-ship	Range			
Lake Huron Central Planning Subarea 3.2								
1	Swartz Creek	Michigan	1	5N	6E	28	1,340	18,500
2	Edwards Lake	Michigan	22	21N	1E	48	920	8,600
3	Salt	Michigan	7	15N	1W	138	580	5,400
4	Salt	Michigan	15	15N	1W	200	920	10,200
5	Chippewa	Michigan	16	14N	2W	420	1,170	15,800
6	Chippewa	Michigan	20	14N	4W	320	3,000	46,700
7	Pine	Michigan	8	12N	5W	101	3,265	45,000
8	South Br. Pine	Michigan	15	13N	6W	-	1,035	10,100
9	Pony Creek	Michigan	26	14N	6W	-	830	13,300
10	South Br. Flint	Michigan	22,23	6N	10E	24	2,200	28,300
11	South Br. Flint	Michigan	18	6N	11E	38	1,100	7,200
12	North Br. Flint	Michigan	13	9N	9E	218	4,300	34,600
13	Farmers Creek	Michigan	13	7N	9E	43	1,000	9,400
14	South Br. Flint	Michigan	26	9N	9E	133	650	5,400
15	Thread Creek	Michigan	29	6N	8E	15	1,100	15,400
16	Thread Creek	Michigan	5	5N	8E	19	920	10,600
17	Yearsley Creek	Michigan	27	7N	8E	63	2,300	35,800
18	Flint	Michigan	27	9N	5E	1,048	800	14,100
19	Brent Run	Michigan	15	9N	5E	37	930	16,400
20	Flint	Michigan	33	10N	5E	1,108	1,050	12,100
21	Flint	Michigan	11	8N	7E	613	2,000	24,300
22	Misteguay Creek	Michigan	2,3	9N	4E	132	500	11,600
23	Cass	Michigan	29	13N	10E	389	940	14,300
24	White Creek	Michigan	29	13N	10E	140	640	4,900
25	East Br. Cass	Michigan	18	13N	12E	227	1,430	21,000
26	South Br. Cass	Michigan	22	13N	12E	139	680	8,600
27	Cass City Creek	Michigan	28	14N	11E	11	1,500	6,500
28	Cass	Michigan	34	12N	8E	721	700	6,600
29	Sucker Creek	Michigan	20	12N	10E	95	630	4,000
30	North Br. Cass	Michigan	10,15	14N	12E	70	910	7,600
31	Cass	Michigan	26	11N	6E	873	1,150	12,200
32	Cass	Michigan	6	13N	11E	368	510	3,400
33	Shiawassee	Michigan	7	8N	3E	594	925	17,700
34	Shiawassee	Michigan	14	6N	3E	441	3,350	48,200
35	Shiawassee	Michigan	24	5N	4E	212	2,670	19,650
36	South Br.Shiawassee	Michigan	29	5N	5E	170	7,750	87,500
37	South Br.Shiawassee	Michigan	28	4N	4E	61	4,080	58,300
38	Bogue Creek	Michigan	36	4N	4E	38	1,970	27,800
39	Cranberry Creek	Michigan	26	4N	5E	5	860	9,700
40	South Br.Shiawassee	Michigan	34	3N	4E	25	3,500	60,400
41	South Br.Shiawassee	Michigan	12	2N	4E	7	1,230	15,900
42	Buckhorn Creek	Michigan	27	4N	7E	8	1,450	28,700
43	Kenyon Lake	Michigan	23	4N	7E	4	1,140	26,000
44	Shiawassee	Michigan	12	4N	7E	14	2,030	49,800
45	Buckhorn Creek	Michigan	10,11	4N	7E	21	860	10,800

TABLE 2–5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Sec-tion	Town-ship	Range	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Huron Central Planning Subarea 3.2 (continued)								
			Latitude		Longitude			
46 e	Flint	Earl Holloway, Mich.	43°	07'	83° 30'	543	1,973	17,700
47 e	Tittabawassee	Sanford Lake, Mich.	43°	41'	84° 23'	1,020	1,526	-
48 e	Tittabawassee	Wixom Lake, Mich.	43°	49'	84° 22'	985	2,178	-
			Sec-tion	Town-ship	Range			
Lake Erie Northwest Planning Subarea 4.1								
1	Black	Michigan	18	7N	16E	-	613	16,100
2	Black	Michigan	18	7N	16E	-	988	34,200
3	Black	Michigan	15	7N	15E	-	548	9,900
4	Black	Michigan	8	7N	15E	-	783	13,400
5	Black	Michigan	29	8N	16E	-	1,971	64,000
6	Pine	Michigan	-	4N	16E	-	907	7,260
7	Pine	Michigan	-	5N	16E	-	1,275	11,470
8	Pine	Michigan	22	5N	16E	-	1,665	18,000
9	Pine	Michigan	16	5N	16E	-	2,875	30,800
10	Pine	Michigan	34	6N	16E	-	604	6,400
11	Pine	Michigan	17	6N	16E	-	507	6,630
12	Belle	Michigan	15	4N	16E	-	688	6,000
13	Belle	Michigan	6	4N	16E	-	780	7,300
14	Belle	Michigan	1	4N	15E	-	820	9,670
15	Belle	Michigan	29	5N	15E	-	596	10,440
16	Belle	Michigan	19	5N	15E	-	689	13,200
17	Belle	Michigan	18	5N	15E	-	616	10,560
18	Belle	Michigan	21	6N	14E	-	1,012	10,780
19	River Raisin	Michigan	10,15	6S	7E	1,039	2,520	17,500
20	River Raisin	Michigan	24	6S	6E	761	1,180	9,100
21	River Raisin	Michigan	1	8S	4E	634	1,170	6,700
22	River Raisin	Michigan	29	6S	4E	463	1,320	19,500
23	Wolfe Creek	Michigan	27	6S	3E	73	1,420	24,400
24	River Raisin	Michigan	21	5S	4E	256	610	6,600
25	River Raisin	Michigan	3	3S	3E	142	1,140	12,400
26	River Raisin	Michigan	29	4S	6E	109	1,170	20,400
27	Saline	Michigan	1	4S	5E	74	4,580	57,800
28	Bear Creek	Michigan	36	7S	1E	-	840	8,400
29	River Rouge	Michigan	27	1S	10E	193	671	5,168
30	River Rouge	Michigan	9	2S	10E	116	599	5,972
31	Honey Creek	Michigan	18,19	1N	4E	84	1,600	18,000
32	Inchwagh Lake	Michigan	26	1N	6E	17	850	7,000
33	Arms Creek	Michigan	4	1S	5E	18	1,025	8,900
34	Fleming Creek	Michigan	25	2S	6E	31	560	8,700
35	Little Portage Lake	Michigan	2	1S	4E	82	790	12,000
36	Ore Creek	Michigan	1	2N	6E	-	514	43,000
37	Mann Creek	Michigan	2,3	2N	6E	31	560	4,500
38	Upper Kent Lake	Michigan	21	2N	7E	143	615	5,000
39	Upper Portage Lake	Michigan	34	1N	3E	-	2,950	19,000
40	Patterson-Bruin Lakes	Michigan	31	1S	3E	65	3,800	41,500
41	Halfmoon Lake	Michigan	32	1S	4E	69	5,100	64,000
42	Honey Mill Creek	Michigan	13	2S	5E	151	8,800	92,000
43	Mill Creek	Michigan	20,29	2S	4E	131	8,800	92,500
44	Elk Lake Creek	Michigan	30,32	8N	12E	22	1,100	14,200
45	East Branch Coon	Michigan	36	4N	13E	44	1,290	11,300
46	Mill Creek	Michigan	27,34	2S	4E	52	1,000	8,700
47	Bear Creek	Michigan	32	8N	3E	15	505	4,217
48	Bear Creek	Michigan	31,32	8N	4E	30	676	2,398

TABLE 2-5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Sec-tion	Town-ship	Range	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Erie Northwest Planning Subarea 4.1 (continued)								
49	Wolf Creek	Michigan	32	6S	3E	64	710	9,900
50	Bear Creek	Michigan	35	7S	1E	10	807	10,750
51	Stoney Creek	Michigan	34	7S	2E	4	840	5,300
52	Saline	Michigan	28,29	4S	6E	104	600	8,320
53 e	Huron	Michigan	24	3S	7E	-	975	-
54 e	Huron	Michigan	24	3S	8E	825	1,425	-
Lake Erie Southwest Planning Subarea 4.2								
1	West Br.St.Joseph	Michigan	7	9S	3W	97	1,600	28,300
2	Bean Creek	Michigan	34	7S	1E	129	2,040	35,000
3	Bean Creek	Michigan	13	8S	1E	138	1,130	17,000
4	Bean Creek	Michigan	28,29	6S	1E	57	1,560	19,000
5	West Br.St.Joseph	Michigan	3,4	8S	3W	29	510	9,200
6	East Br.St.Joseph	Michigan	32	7S	1W	29	560	8,300
7	St. Marys	Ohio	-	-	-	69	4,990	41,433
8	Little Auglaize Basin	Ohio	-	-	-	14	528	2,210
9	Little Auglaize Basin	Ohio	-	-	-	121	760	3,253
10	Little Auglaize Basin	Ohio	-	-	-	59	1,190	6,844
11	Little Auglaize Basin	Ohio	-	-	-	55	875	4,911
12	Little Auglaize Basin	Ohio	-	-	-	31	636	3,437
13	Little Auglaize Basin	Ohio	-	-	-	25	2,000	10,650
14	Upper Auglaize Basin	Ohio	-	-	-	29	3,020	12,921
15	Upper Auglaize Basin	Ohio	-	-	-	198	1,600	16,389
16	Upper Auglaize Basin	Ohio	-	-	-	195	1,060	9,545
17	Upper Auglaize Basin	Ohio	-	-	-	188	1,730	14,762
18	Upper Auglaize Basin	Ohio	-	-	-	155	1,180	9,177
19	Upper Auglaize Basin	Ohio	-	-	-	154	784	4,327
20	Upper Auglaize Basin	Ohio	-	-	-	152	802	7,366
21	Upper Auglaize Basin	Ohio	-	-	-	151	574	4,604
22	Upper Auglaize Basin	Ohio	-	-	-	150	965	8,931
23	Upper Auglaize Basin	Ohio	-	-	-	149	794	6,292
24	Upper Auglaize Basin	Ohio	-	-	-	149	702	5,033
25	Ottawa River Basin	Ohio	-	-	-	23	1,230	10,588
26	Ottawa River Basin	Ohio	-	-	-	23	1,180	9,698
27	Ottawa River Basin	Ohio	-	-	-	247	939	5,678
28	Ottawa River Basin	Ohio	-	-	-	246	852	5,095
29	Ottawa River Basin	Ohio	-	-	-	107	1,080	11,663
30	Lower Blanchard Basin	Ohio	-	-	-	39	611	3,806
31	Upper Blanchard Basin	Ohio	-	-	-	9	532	2,630

TABLE 2–5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Sec-tion	Dam Location Town-ship	Dam Location Range	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Erie Southwest Planning Subarea 4.2 (continued)								
32	Upper Blanchard Basin	Ohio	-	-	-	110	1,700	16,880
33	Upper Blanchard Basin	Ohio	-	-	-	110	1,570	15,253
34	Upper Blanchard Basin	Ohio	-	-	-	85	750	5,739
35	Upper Blanchard Basin	Ohio	-	-	-	81	2,800	24,092
36	Upper Blanchard Basin	Ohio	-	-	-	65	5,360	45,730
37	Upper Maumee-- Lower Auglaize Basins	Ohio	-	-	-	25	1,020	5,586
38	Upper Maumee-- Lower Auglaize Basins	Ohio	-	-	-	98	671	4,757
39	Upper Maumee-- Lower Auglaize Basins	Ohio	-	-	-	27	584	4,481
40	Tiffin River Basin	Ohio	-	-	-	799	10,400	117,547
41	Tiffin River Basin	Ohio	-	-	-	20	550	5,709
42	Tiffin River Basin	Ohio	-	-	-	796	8,670	95,756
43	Tiffin River Basin	Ohio	-	-	-	56	814	8,379
44	Tiffin River Basin	Ohio	-	-	-	712	7,720	85,321
45	Tiffin River Basin	Ohio	-	-	-	106	1,530	15,929
46	Tiffin River Basin	Ohio	-	-	-	30	1,050	14,118
47	Tiffin River Basin	Ohio	-	-	-	29	833	10,128
48	Tiffin River Basin	Ohio	-	-	-	10	599	6,476
49	Tiffin River Basin	Ohio	-	-	-	9	679	6,752
50	Tiffin River Basin	Ohio	-	-	-	604	5,730	59,541
51	Tiffin River Basin	Ohio	-	-	-	64	1,610	12,890
52	Tiffin River Basin	Ohio	-	-	-	35	590	4,818
53	Tiffin River Basin	Ohio	-	-	-	508	3,070	27,775
54	Tiffin River Basin	Ohio	-	-	-	31	618	8,501
55	Tiffin River Basin	Ohio	-	-	-	29	653	5,217
56	Tiffin River Basin	Ohio	-	-	-	21	677	6,015
57	Tiffin River Basin	Ohio	-	-	-	445	1,050	4,420
58	Tiffin River Basin	Ohio	-	-	-	32	690	5,248
59	St. Joseph River Basin	Ohio	-	-	-	570	2,720	28,328
60	St. Joseph River Basin	Ohio	-	-	-	114	875	7,304
61	St. Joseph River Basin	Ohio	-	-	-	432	4,040	36,215
62	St. Joseph River Basin	Ohio	-	-	-	24	1,220	10,067
63	St. Joseph River Basin	Ohio	-	-	-	20	1,110	14,149
64	St. Joseph River Basin	Ohio	-	-	-	117	1,210	17,034
65	St. Joseph River Basin	Ohio	-	-	-	114	1,020	14,916
66	Middle Maumee River Basin	Ohio	-	-	-	144	970	8,931
67	Middle Maumee River Basin	Ohio	-	-	-	143	845	6,844
68	Middle Maumee River Basin	Ohio	-	-	-	73	823	7,243
69	Middle Maumee River Basin	Ohio	-	-	-	73	801	6,967

TABLE 2–5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Sec-tion	Town-ship	Range	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Erie Southwest Planning Subarea 4.2 (continued)								
70	Middle Maumee River Basin	Ohio	–	–	–	14	705	4,880
71	Middle Maumee River Basin	Ohio	–	–	–	14	650	4,266
72	Middle Maumee River Basin	Ohio	–	–	–	29	542	6,813
73	Middle Maumee River Basin	Ohio	–	–	–	178	1,110	11,233
74	Middle Maumee River Basin	Ohio	–	–	–	177	978	9,146
75	Lower Maumee Basin	Ohio	–	–	–	196	1,760	25,289
76	Lower Maumee Basin	Ohio	–	–	–	194	1,520	20,041
77	Lower Maumee Basin	Ohio	–	–	–	188	1,630	20,317
78	Lower Maumee Basin	Ohio	–	–	–	148	748	7,611
79	Lower Maumee Basin	Ohio	–	–	–	144	733	5,340
80	Lower Maumee Basin	Ohio	–	–	–	83	714	4,297
81	Lower Maumee Basin	Ohio	–	–	–	78	660	4,604
82	Lower Maumee Basin	Ohio	–	–	–	77	1,100	8,133
83	Lower Maumee Basin	Ohio	–	–	–	76	872	6,292
84	Lower Maumee Basin	Ohio	–	–	–	71	1,250	9,698
85	Lower Maumee Basin	Ohio	–	–	–	69	1,080	8,164
86	Lower Maumee Basin	Ohio	–	–	–	69	994	7,059
87	Lower Maumee Basin	Ohio	–	–	–	58	799	6,261
88	Lower Maumee Basin	Ohio	–	–	–	36	528	5,064
89	Lower Maumee Basin	Ohio	–	–	–	34	729	4,726
			Latitude		Longitude			
90	Tymochtee Creek	Ohio	40° 55' 30"		83° 20' 30"	225	801	6,199
91	Tymochtee Creek	Ohio	40° 53'		83° 22'	206	1,090	8,592
92	Tymochtee Creek	Ohio	40° 51'		83° 22' 30"	200	1,630	15,282
93	Tymochtee Creek	Ohio	40° 48'		83° 21' 30"	170	1,660	17,829
94	Tymochtee Creek	Ohio	40° 48'		83° 21' 30"	149	1,150	11,446
95	Tymochtee Creek	Ohio	40° 45'		83° 23'	141	646	6,014
96	Tymochtee Creek	Ohio	40° 42'		83° 24'	129	1,520	11,538
97	Tymochtee Creek	Ohio	40° 41'		83° 24'	128	1,380	9,850
98	Tymochtee Creek	Ohio	40° 40' 30"		83° 23' 30"	62.1	941	6,076
99	Sandusky	Ohio	40° 51'		83° 15'	300	1,860	29,336
100	Sandusky	Ohio	40° 43'		83° 16'	286	1,640	20,560
101	Sandusky	Ohio	40° 47'		83° 14'	284	2,410	33,172
102	Sandusky	Ohio	40° 46'		83° 14'	280	4,530	57,966
103	Sandusky	Ohio	40° 46'		83° 13'	280	4,360	53,363
104	Broken Sword Creek	Ohio	40° 47'		83° 10'	89.2	914	9,666
105	Broken Sword Creek	Ohio	40° 48'		83° 09' 30"	87.5	644	5,892
106	Broken Sword Creek	Ohio	40° 49'		83° 09'	31.0	625	7,518
107	Broken Sword Creek	Ohio	40° 50'		83° 09'	79.7	860	11,385
108	Broken Sword Creek	Ohio	40° 50'		83° 07'	68.5	682	8,991
109	Broken Sword Creek	Ohio	40° 51'		83° 05'	66.5	790	6,935
110	Broken Sword Creek	Ohio	40° 51'		83° 04'	61.5	1,570	13,440
111	Broken Sword Creek	Ohio	40° 52'		83° 03'	59.8	1,270	9,758
112	Sandusky	Ohio	40° 45' 30"		83° 08' 30"	117	876	14,637
113	Sandusky	Ohio	40° 46'		83° 05'	104	519	4,572
114	Sandusky	Ohio	40° 46'		83° 04' 30"	100	731	8,991
115	Sandusky	Ohio	40° 46'		83° 04'	99.7	599	6,628
116	Sandusky	Ohio	40° 47'		83° 03'	96.3	659	7,672
117	Sandusky	Ohio	40° 49' 30"		82° 55'	78.3	3,260	44,894
118	Tributary Sandusky	Ohio	40° 50'		82° 53' 30"	70.4	821	9,574
119	Tymochtee Creek	Ohio	40° 57'		83° 18'	291	2,970	40,076
120	Tymochtee Creek	Ohio	40° 56' 30"		83° 18' 30"	261	2,060	26,728

TABLE 2-5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Sec-tion / Latitude	Town-ship Range / Longitude	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Erie Southwest Planning Subarea 4.2 (continued)							
121	Little Tymochtee Creek	Ohio	40^{o} 56'	83^{o} 19'	31.0	543	5,800
122	Honey Creek	Ohio	41^{o} 03'	83^{o} 10'	169	820	17,829
123	Honey Creek	Ohio	41^{o} 03' 30"	82^{o} 55'	83.1	1,780	10,004
124	Sandusky	Ohio	41^{o} 04'	83^{o} 12'	772	7,350	100,466
125	Sandusky	Ohio	41^{o} 03'	83^{o} 12'	770	6,750	87,148
126	Sandusky	Ohio	41^{o} 01'	83^{o} 12'	765	5,810	67,693
127	Sandusky	Ohio	40^{o} 54'	83^{o} 14' 30"	337	1,810	23,475
128	Sandusky	Ohio	40^{o} 53'	83^{o} 14'	314	1,960	26,329
129	Sandusky	Ohio	40^{o} 52'	83^{o} 15' 30"	312	1,650	20,866
130	Rock	Ohio	41^{o} 04'	83^{o} 06'	25.1	625	6,475
131	Armstrong & Biegly	Ohio	41^{o} 05'	83^{o} 04' 30"	16.8	619	5,523
132 e	St. Marys	Ohio	-	-	118	13,440	130,175
133 e	Auglaize	Ohio	41^{o} 14'	84^{o} 24'	2,329	1,240	9,800
134 e	Maumee	Ohio	-	-	-	600	-
135 e	Maumee	Ohio	-	-	-	2,100	-
136	Huron River Basin	Ohio	-	-	355.0	1,100	3,050
137	Huron River Basin	Ohio	-	-	86.6	857	1,900
138	Huron River Basin	Ohio	-	-	244.0	578	1,640
139	Huron River Basin	Ohio	-	-	123.0	1,500	2,840
140	Huron River Basin	Ohio	-	-	123.0	1,380	2,530
141	Huron River Basin	Ohio	-	-	122.0	1,220	2,100
142	Huron River Basin	Ohio	-	-	121.0	1,100	1,790
143	Huron River Basin	Ohio	-	-	97.3	844	1,620
144	Huron River Basin	Ohio	-	-	93.5	577	870
145	Huron River Basin	Ohio	-	-	93.1	709	1,230
146	Huron River Basin	Ohio	-	-	87.7	612	1,200
147	Huron River Basin	Ohio	-	-	87.4	541	980
148	Huron River Basin	Ohio	-	-	86.3	512	920
149	Vermilion River Basin	Ohio	-	-	261.0	853	3,440
150	Vermilion River Basin	Ohio	-	-	250.0	576	1,970
151	Vermilion River Basin	Ohio	-	-	242.0	1,180	4,540
152	Vermilion River Basin	Ohio	-	-	33.8	516	1,420
153	Vermilion River Basin	Ohio	-	-	206.0	792	3,710
154	Vermilion River Basin	Ohio	-	-	204.0	706	3,050
155	Vermilion River Basin	Ohio	-	-	201.0	1,570	3,790
156	Vermilion River Basin	Ohio	-	-	198.0	1,940	4,160
157	Vermilion River Basin	Ohio	-	-	183.0	1,690	3,640
158	Vermilion River Basin	Ohio	-	-	178.0	1,190	2,150
159	Vermilion River Basin	Ohio	-	-	178.0	1,060	1,820
160	Vermilion River Basin	Ohio	-	-	36.8	585	920
161	Vermilion River Basin	Ohio	-	-	139.0	632	990
162	Vermilion River Basin	Ohio	-	-	127.0	706	610
163	Vermilion River Basin	Ohio	-	-	114.0	717	1,030

TABLE 2–5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location: Sec-tion	Dam Location: Town-ship	Dam Location: Range	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Erie Southwest Planning Subarea 4.2 (continued)			Latitude	Longitude				
164	Vermilion River Basin	Ohio	-	-		108.0	1,130	1,420
165	Vermilion River Basin	Ohio	-	-		105.0	1,960	2,000
166	Vermilion River Basin	Ohio	-	-		24.7	949	970
Lake Erie Central Planning Subarea 4.3								
1	Conneaut Creek	Ohio	41° 54'	80° 38'		165	725	21,296
2	Conneaut Creek	Ohio	41° 53'	80° 37'		160	1,160	43,114
3	Conneaut Creek	Ohio	41° 54'	80° 33'		156	970	22,861
4	Ashtabula	Ohio	41° 50'	80° 44'		113	4,500	70,578
5	Ashtabula	Ohio	41° 51'	80° 42' 30"		93.7	995	16,540
6	Ashtabula	Ohio	41° 51'	80° 40'		91.6	800	11,415
7	Ashtabula	Ohio	41° 51'	80° 39'		90.2	675	9,267
8	Rock Creek	Ohio	41° 36'	80° 49'		68.5	4,300	30,993
9	Grand	Ohio	41° 22'	80° 59'		27.0	570	7,303
10	Aurora Creek	Ohio	41° 25'	81° 25'		57.2	956	20,800
11	Aurora Creek	Ohio	41° 23' 30"	81° 24'		50.8	820	19,500
12	Aurora Creek	Ohio	41° 22'	81° 22' 30"		30.3	548	15,400
13	Chagrin	Ohio	41° 37' 30"	81° 24' 30"		247	2,890	110,500
14	East Br. Chagrin	Ohio	41° 37' 30"	81° 23'		50.4	1,200	43,400
15	East Br. Chagrin	Ohio	41° 37' 30"	81° 22' 30"		45.6	1,000	36,700
16	East Br. Chagrin	Ohio	41° 37' 30"	81° 21' 30"		41.5	859	37,500
17	East Br. Chagrin	Ohio	41° 36'	81° 17'		24.2	1,070	35,500
18	East Br. Chagrin	Ohio	41° 34' 30"	81° 18' 30"		20.7	731	15,940
19	Chagrin	Ohio	41° 35'	81° 24' 30"		179	2,070	82,100
20	Chagrin	Ohio	41° 33'	81° 25'		172	1,420	43,900
21	Chagrin	Ohio	41° 30' 30"	81° 24' 30"		158	1,625	53,700
22	Chagrin	Ohio	41° 29' 30"	81° 24'		155	1,380	45,100
23	Tributary of Chagrin	Ohio	41° 27'	81° 23'		57.5	918	21,300
24	Tributary of Chagrin	Ohio	41° 28'	81° 21' 30"		55.0	1,390	29,700
25	Tributary of Chagrin	Ohio	41° 28'	81° 20'		12.0	766	17,400
26	Cuyahoga	Ohio	41° 25' 30"	81° 09'		-	3,860	46,430
27	West Br. of Cuyahoga	Ohio	41° 28' 30"	81° 11'		26.4	2,320	33,430
28	West Br. of Cuyahoga	Ohio	41° 30'	81° 10'		22.1	3,250	41,300
29	Congress Lake Outlet	Ohio	41° 8' 30"	81° 16' 30"		60.7	5,200	61,600
30	Congress Lake Outlet	Ohio	41° 01'	81° 16'		15.5	917	8,320
31	Cuyahoga	Ohio	41° 14' 30"	81° 18'		184	5,620	61,540
32	Tributary of Cuyahoga	Ohio	41° 15'	81° 16'		177	5,000	51,960
33	Tributary of Cuyahoga	Ohio	41° 16'	81° 14' 30"		169	7,930	95,070
34	Cuyahoga	Ohio	41° 21' 30"	81° 09' 30"		136	11,240	141,500
35	Bridge Creek	Ohio	41° 25'	81° 10'		39.3	1,560	10,190
36	Bridge Creek	Ohio	41° 24' 30"	81° 11'		27.8	1,400	18,170
37	Cuyahoga	Ohio	41° 14'	81° 33'		520	4,390	173,200
38	Furnace Run	Ohio	41° 12' 30"	81° 35' 30"		14.5	713	41,900
39	Furnace Run	Ohio	41° 13'	81° 35' 30"		13.1	511	28,700
40	Mud Branch	Ohio	41° 09'	81° 31' 30"		25.8	979	7,230
41	Mud Branch	Ohio	41° 09' 30"	81° 30'		24.5	2,280	20,620

TABLE 2–5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location Latitude	Dam Location Longitude	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Erie Central Planning Subarea 4.3 (continued)							
42	Cuyahoga	Ohio	41° 22'	81° 37'	703	5,060	232,100
43	Tinkers Creek	Ohio	41° 23'	81° 31'	84.5	967	14,050
44	Tributary of Tinkers Creek	Ohio	41° 22'	81° 28' 30"	67.3	1,500	19,620
45	Tributary of Tinkers Creek	Ohio	41° 17'	81° 24' 30"	416	4,920	45,830
46	Cuyahoga	Ohio	41° 19'	81° 35' 30"	590	5,890	289,400
47 e	Bridge Creek	Ohio	41° 24'	81° 12'	27.8	1,500	18,110
48 e	Cuyahoga	Ohio	41° 11'	81° 20'	207	769	7,060
49 e	Little Cuyahoga	Ohio	41° 4'	81° 22'	14.3	900	6,900
50	Black River Basin	Ohio	-	-	170.0	540	330
51	Black River Basin	Ohio	-	-	163.0	743	640
52	Black River Basin	Ohio	-	-	160.0	874	750
53	Black River Basin	Ohio	-	-	129.0	1,390	1,750
54	Black River Basin	Ohio	-	-	90.6	794	850
55	Black River Basin	Ohio	-	-	81.8	781	910
56	Black River Basin	Ohio	-	-	36.8	664	1,250
57	Black River Basin	Ohio	-	-	29.3	617	1,220
58	Black River Basin	Ohio	-	-	29.0	685	1,360
59	Black River Basin	Ohio	-	-	28.4	524	870
60	Black River Basin	Ohio	-	-	28.0	676	1,250
61	Black River Basin	Ohio	-	-	25.9	527	890
62	Black River Basin	Ohio	-	-	185.0	500	830
63	Black River Basin	Ohio	-	-	170.0	722	680
64	Black River Basin	Ohio	-	-	167.0	1,400	1,670
65	Black River Basin	Ohio	-	-	156.0	1,310	1,210
66	Black River Basin	Ohio	-	-	74.6	665	710
67	Rocky River Basin	Ohio	-	-	289.0	2,380	12,460
68	Rocky River Basin	Ohio	-	-	62.5	1,150	2,400
69	Rocky River Basin	Ohio	-	-	58.5	1,420	3,190
70	Rocky River Basin	Ohio	-	-	58.3	1,870	4,520
71	Rocky River Basin	Ohio	-	-	56.6	1,580	3,350
72	Rocky River Basin	Ohio	-	-	52.4	1,320	2,560
73	Rocky River Basin	Ohio	-	-	48.0	1,050	1,860
74	Rocky River Basin	Ohio	-	-	47.3	930	1,490
75	Rocky River Basin	Ohio	-	-	42.7	517	590
76	Rocky River Basin	Ohio	-	-	147.0	619	500
77	Rocky River Basin	Ohio	-	-	146.0	1,040	1,050
78	Rocky River Basin	Ohio	-	-	139.0	924	910
79	Rocky River Basin	Ohio	-	-	124.0	776	900
80	Rocky River Basin	Ohio	-	-	117.0	816	1,730
81	Rocky River Basin	Ohio	-	-	28.5	863	930
82	Rocky River Basin	Ohio	-	-	15.4	1,120	1,460
83	Rocky River Basin	Ohio	-	-	22.7	532	1,020
			County	Town			
Lake Erie East Planning Subarea 4.4							
1	Cattaraugus Creek	Arcade Center, N.Y.	Wyoming	Arcade	24.9	1,020	32,000
2	South Br.Cattaraugus Creek	Otto, N.Y.	Cattaraugus	Otto	64.5	4,450	150,000
3	Cattaraugus Creek	Springville, N.Y.	Erie and Cattaraugus	Concord & Ashford	225	3,770	255,000
4	Cattaraugus Creek	Zoar, N.Y.	Erie and Cattaraugus	Collins & Otto	317.9	2,600	203,000
5	Clear Creek	Bagdad, N.Y.	Erie	Collins	20.0	370	9,000
6	Tonawanda Creek	Alabama Ponds, N.Y.	Genesee & Niagara	Alabama & Royalton		2,800	
7	Cayuga Creek	Bennington, N.Y.	Wyoming	Bennington	32.0	610	26,500

TABLE 2–5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location County	Dam Location Town	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Erie East Planning Subarea 4.4 (continued)							
8	Little Tonawanda Creek	Linden, N.Y.	Genesee	Bethany	–	920	22,900
9	Ellicott Creek	Sandridge, N.Y.	Erie	Alden	33.4	1,400	20,400
10	Tonawanda Creek	Sierks, N.Y.	Wyoming	Attica	61.3	810	36,200
11	Cazenovia Creek	Spring Brook, N.Y.	Erie	Elma	121.0	1,590	67,000
12	Buffalo Creek	Wales, N.Y.	Erie	Wales	77.9	1,320	49,000
Lake Ontario West Planning Subarea 5.1							
1	Black Creek	No. 7-2, N.Y.	Allegany	Birdsall	15.7	1,720	37,700
2	Jaycox Creek	No. 15-2, N.Y.	Livingston	Geneseo	10.0	720	6,450
3	Conesus Inlet	No. 16-4, N.Y.	Livingston	Conesus	16.1	710	9,450
4	Honeoye Inlet	No. 17-5, N.Y.	Ontario	Canadice & Richmond	18.0	1,100	9,000
5	Gates Creek	No. 17-12, N.Y.	Ontario	West Bloomfield	17.0	500	9,250
6	Angelica Creek	Angelica, N.Y.	Allegany	Angelica	54	1,590	28,800
7	Genesee	Belfast, N.Y.	Allegany	Belfast	578	1,800	48,000
8	Oatka Creek	Oatka, N.Y.	Monroe	Wheatland	161	860	44,500
9	Genesee	Portage, N.Y.	Livingston & Wyoming	Portage & Genesee Falls	985	4,100	124,000
10	Genesee	Stannard, N.Y.	Allegany	Willing	168	1,280	39,000
11	Keshequa Creek	Tuscarora, N.Y.	Livingston	Mount Morris	69	940	42,000
12	Wiscoy Creek	Wiscoy, N.Y.	Allegany	Hume	108	900	43,200
13 e	Canadice Outlet	Canadice Lake, N.Y.	Ontario	Canadice	12.6	640	–
14 e	Conesus Creek	Conesus Lake, N.Y.	Livingston	Livonia	69.8	3,200	–
15 e	Hemlock Outlet	Hemlock, N.Y.	Livingston	Livonia	43.0	1,860	–
16 e	Caneadea Creek	Rushford Lake, N.Y.	Allegany	Caneadea	61.0	580	–
17 e	Silver Lake Outlet	Silver Lake, N.Y.	Wyoming	Castile	17.7	770	–
18 e	Honeoye Creek	Honeoye Lake, N.Y.	Ontario	Richmond	41.1	1,790	–
19 e	Genesee	Mount Morris, N.Y.	Livingston	Leicester	1,077	3,680	337,000
Lake Ontario Central Planning Subarea 5.2							
1 e	Salmon	Salmon Res., N.Y.	Oswego	Orwell	191	2,640	–
2	Limestone Creek	New York	Onondaga	Pompey	46.8	1,420	37,000
3	Virgil Creek	New York	Cortland	Virgil	14.0	475	11,250
4	Chittenango Creek	New York	Madison	Nelson	25.0	1,150	19,800
5	Mad	New York	Oneida	Florence	22.8	920	18,200
6	Sucker Brook	New York	Lewis	High Market	7.7	550	13,150
7	East Br.Fish Creek	New York	Lewis	High Market	30.5	600	23,100
8	East Br.Fish Creek	New York	Lewis	High Market	41.3	1,000	33,000
9	Point Rock Creek	New York	Lewis	Lewis	14.1	770	12,000
10	Florence Creek	New York	Oneida	Florence	6.1	610	18,200
11	Caughdenoy Creek	New York	Oswego	Hastings	13.6	1,460	12,300
12	Black Creek	New York	Wayne	Galen	14.6	780	5,530
13	Mud Creek	Bristol Center, N.Y.	Ontario	Bristol	22.5	560	10,100
14	West	New York	Yates	Middlesex	38.5	1,020	26,200
15	Kashong Creek	New York	Yates	Benton	5.5	790	12,800
16	Black Br.	New York	Seneca	Waterloo	7.2	1,170	2,160
17	Kendig Creek	New York	Seneca	Fayette	12.8	1,270	16,650
18	Brook Creek	New York	Seneca	Junius	6.0	550	6,050
19	Red Creek	New York	Seneca	Varick	3.5	610	3,060
20	Fall Creek	New York	Cayuga	Summerhill	20.3	940	16,200
21	Salmon Creek	New York	Cayuga	Lansing	81.4	1,000	65,000
22	Muskrat Creek	New York	Cayuga	Cato	23.4	2,760	21,800
23	North Brook	New York	Cayuga	Throop	11.3	544	4,320
24	Owasco Inlet Trib.	New York	Tompkins	Groton	4.0	260	1,550
25	Bear Swamp Creek	New York	Cayuga	Niles	7.5	960	31,100

TABLE 2-5(continued) Existing and Potential Reservoir Sites

Map Index Number	River	Name or State	Dam Location County	Dam Location Town	Drainage Area (sq mi)	Pond Area (ac)	Storage Capacity (ac-ft)
Lake Ontario Central Planning Subarea 5.2 (continued)							
26	Flint Creek	New York	Yates	Potter	26.0	980	20,700
27 e	Canandaigua Outlet	Canandaigua Lake, N.Y.	Ontario	Canandaigua	189	10,600	-
28 e	Seneca	Cayuga Lake, N.Y.	Cayuga & Seneca Falls	Aurelius & Seneca	1,587	42,500	-
29 e	Chittenango Creek	Cazenovia, N.Y.	Madison	Cazenovia	9	1,060	-
30 e	Limestone Creek	De Ruyter Res., N.Y.	Cortland & Madison	Cuyler & De Ruyter	19	560	-
31 e	Keuka Outlet	Keuka Lake, N.Y.	Yates	Penn Yan	179	11,200	-
32 e	Oneida	Oneida Lake, N.Y.	Oswego	West Monroe	1,377	51,100	-
33 e	Ninemile Creek	Otisco Lake, N.Y.	Onondaga	Spafford, Otisco	45	2,200	-
34 e	Owasco Outlet	Owasco Lake, N.Y.	Cayuga	Auburn	204	6,650	-
35 e	Seneca	Seneca Lake, N.Y.	Seneca	Fayette & Waterloo	714	42,700	-
36 e	Skaneateles	Skaneateles Lake, N.Y.	Onondaga	Skaneateles	75.8	8,840	-
Lake Ontario East Planning Subarea 5.3							
1	Oswegatchie	High Rock, N.Y.	St.Lawrence	Fine	66	6,800	240,000
2	Oswegatchie	Richville, N.Y.	St.Lawrence	De Kalb	841	16,100	624,000
3	Oswegatchie	Talcville, N.Y.	St.Lawrence	Edwards	338	4,400	148,000
4	Greenwood Creek	Pitcairn, N.Y.	St.Lawrence	Pitcairn	30	2,000	46,000
5 e	Oswegatchie	Cranberry Lake, N.Y.	St.Lawrence	Clifton	144	7,080	58,000
6 e	Indian River Trib.	Lake Bonaparte, N.Y.	Lewis	Diana	22	1,390	2,100
7	Elm Creek	Elm Cr Diversion,N.Y.	St.Lawrence	Hermon	371	6,300	330,000
8	Harrison Creek	Harrison Creek, N.Y.	St.Lawrence	Canton	422	2,900	74,000
9	Grass	Clare, N.Y.	St.Lawrence	Russell	268	2,800	50,000
10	Little	Pierrepont, N.Y.	St.Lawrence	Russell	19	2,000	45,000
11	Raquette & Jordan	Jordan, N.Y.	St.Lawrence	Colton	830	24,000	745,000
12	So.Br. Grass & Raquette	Irish Hill Diversion, N.Y.	Franklin	Clifton	1,042	14,400	273,000
13 e	Bog	Lows Lake, N.Y.	St.Lawrence	Colton	36	2,160	23,000
14 e	Raquette	Tupper Lake, N.Y.	St.Lawrence	Piercefield	723	5,970	19,000
15 e	Raquette	Carry Falls Res., N.Y.	St.Lawrence	Colton	877	3,500	114,000
16 e	Raquette	Blake Falls Res., N.Y.	St.Lawrence	Parishville	907	660	3,900
17 e	Raquette	Rainbow Falls Res., N.Y.	St.Lawrence	Colton	929	710	9,400
18	Black	Forestport, N.Y.	Oneida	Boonville	237	11,700	512,000
19	Black	Hawkinsville, N.Y.	Oneida	Boonville	265	10,000	450,000
20	So. Branch Moose	Higley Mountain, N.Y.	Herkimer	Ohio	131	8,170	274,000
21	Middle Br. Moose	Nelson Lake, N.Y.	Herkimer	Webb	148	2,150	71,500
22	So. Branch Moose	Panther Mountain, N.Y.	Herkimer	Webb	200	4,250	410,000
23	Independence	Sperryville, N.Y.	Lewis	Watson	85	2,660	65,000
24 e	Middle Br. Moose	First-Fifth Lake, N.Y.	Herkimer	Webb	52	3,260	20,600
25 e	Black	Forestport Res., N.Y.	Oneida	Forestport	144	640	4,900
26 e	Middle Br. Moose	Sixth-Seventh Lake, N.Y.	Hamilton	Inlet	17	960	6,900
27 e	South Branch Black	South Lake, N.Y.	Herkimer	Ohio	6	500	9,700
28 e	Beaver	Stillwater Res., N.Y.	Herkimer	Webb	172	6,340	100,000
29 e	Woodhull Creek	Woodhull Lake, N.Y.	Herkimer	Webb	6.5	1,150	20,000

[e] Existing

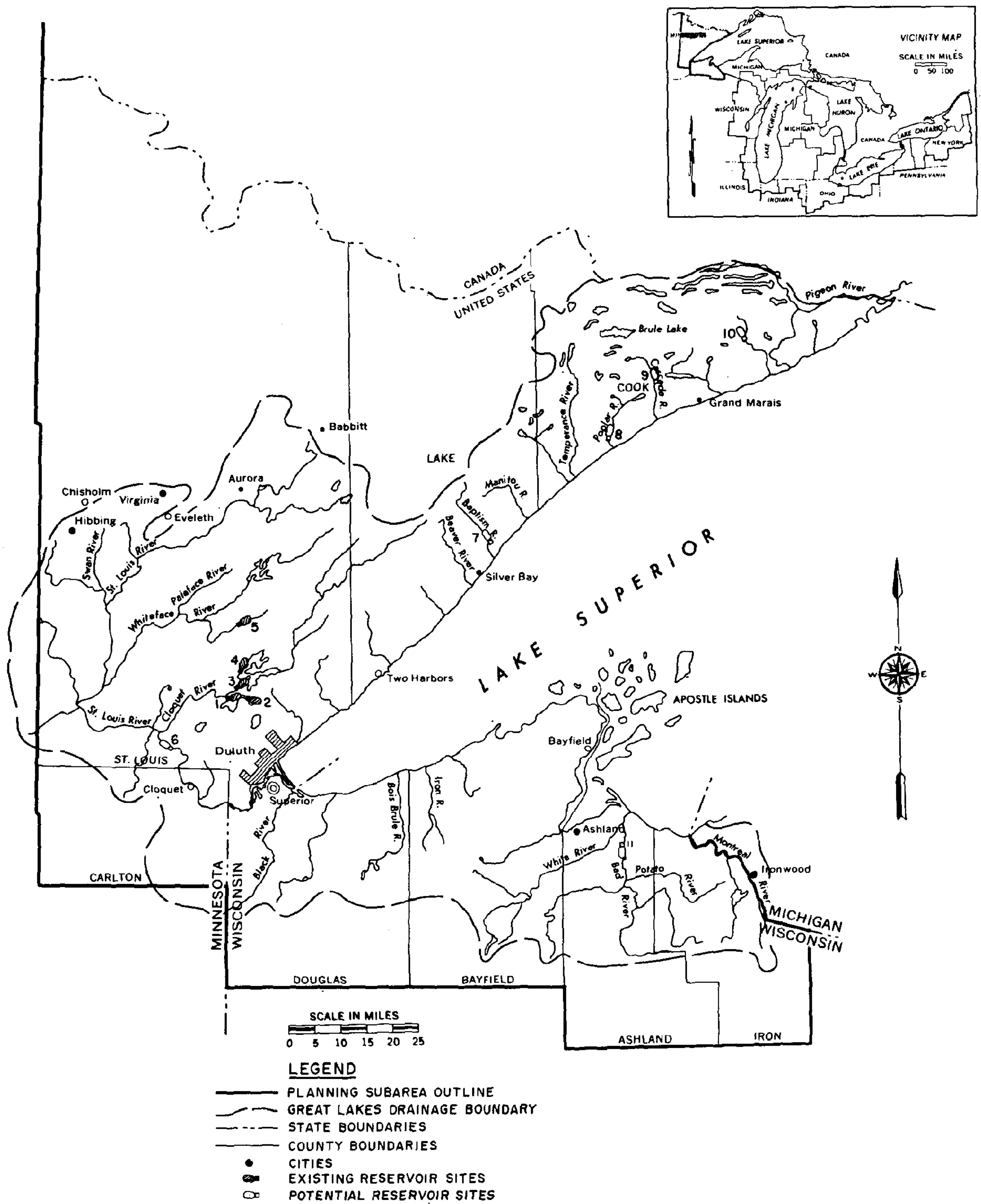


FIGURE 2-80 Reservoir Site Map, Planning Subarea 1.1

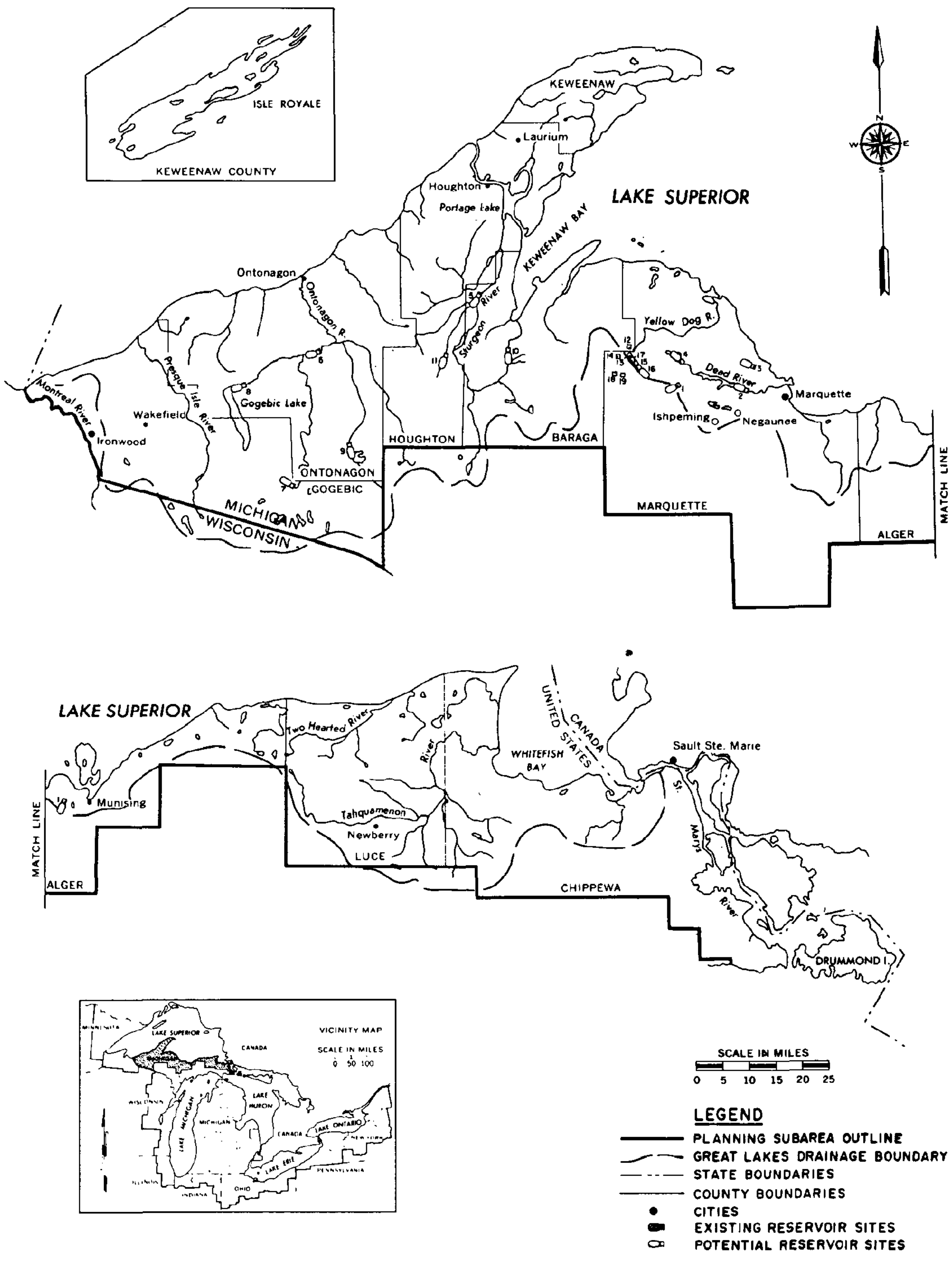


FIGURE 2–81 Reservoir Site Map, Planning Subarea 1.2

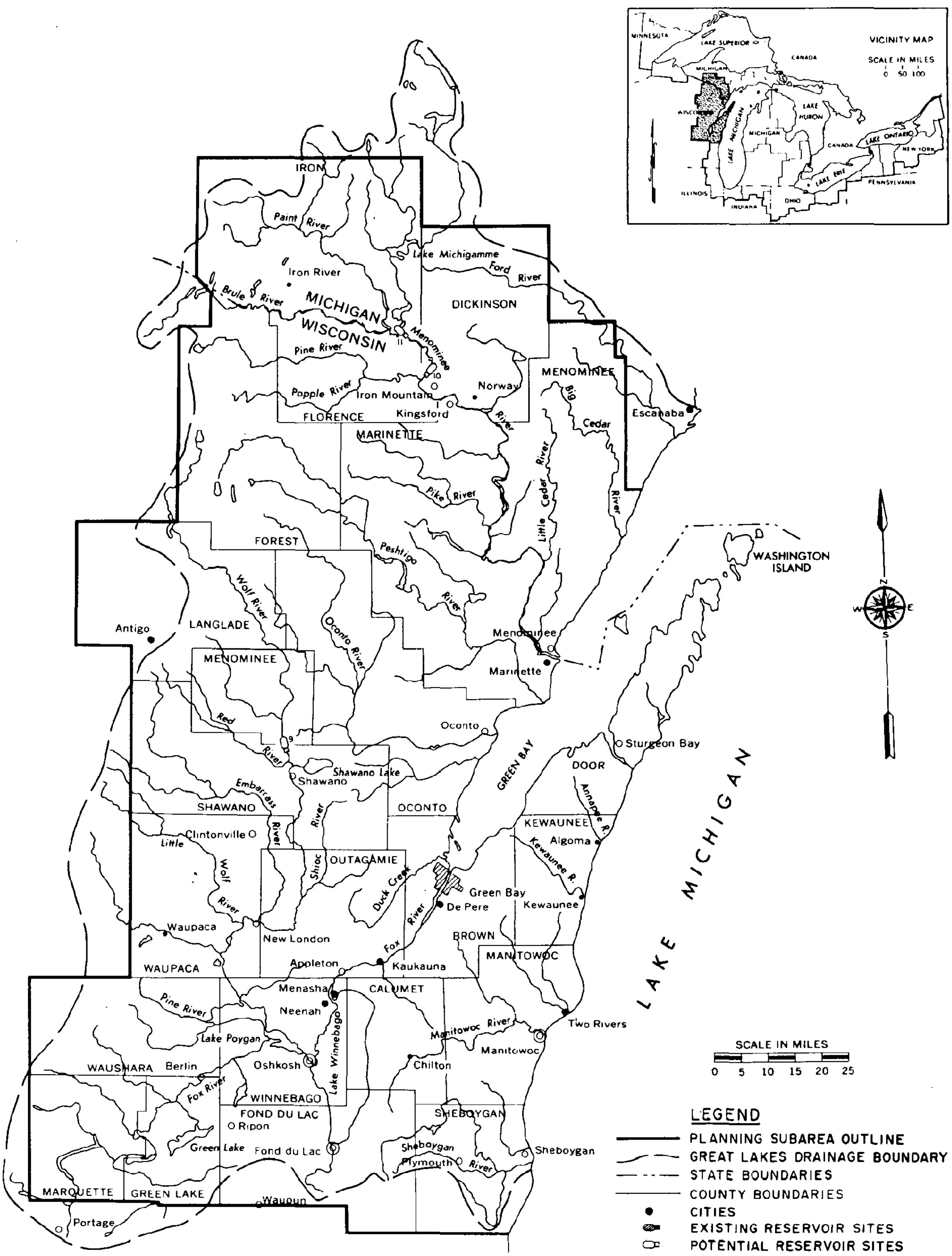


FIGURE 2–82 Reservoir Site Map, Planning Subarea 2.1

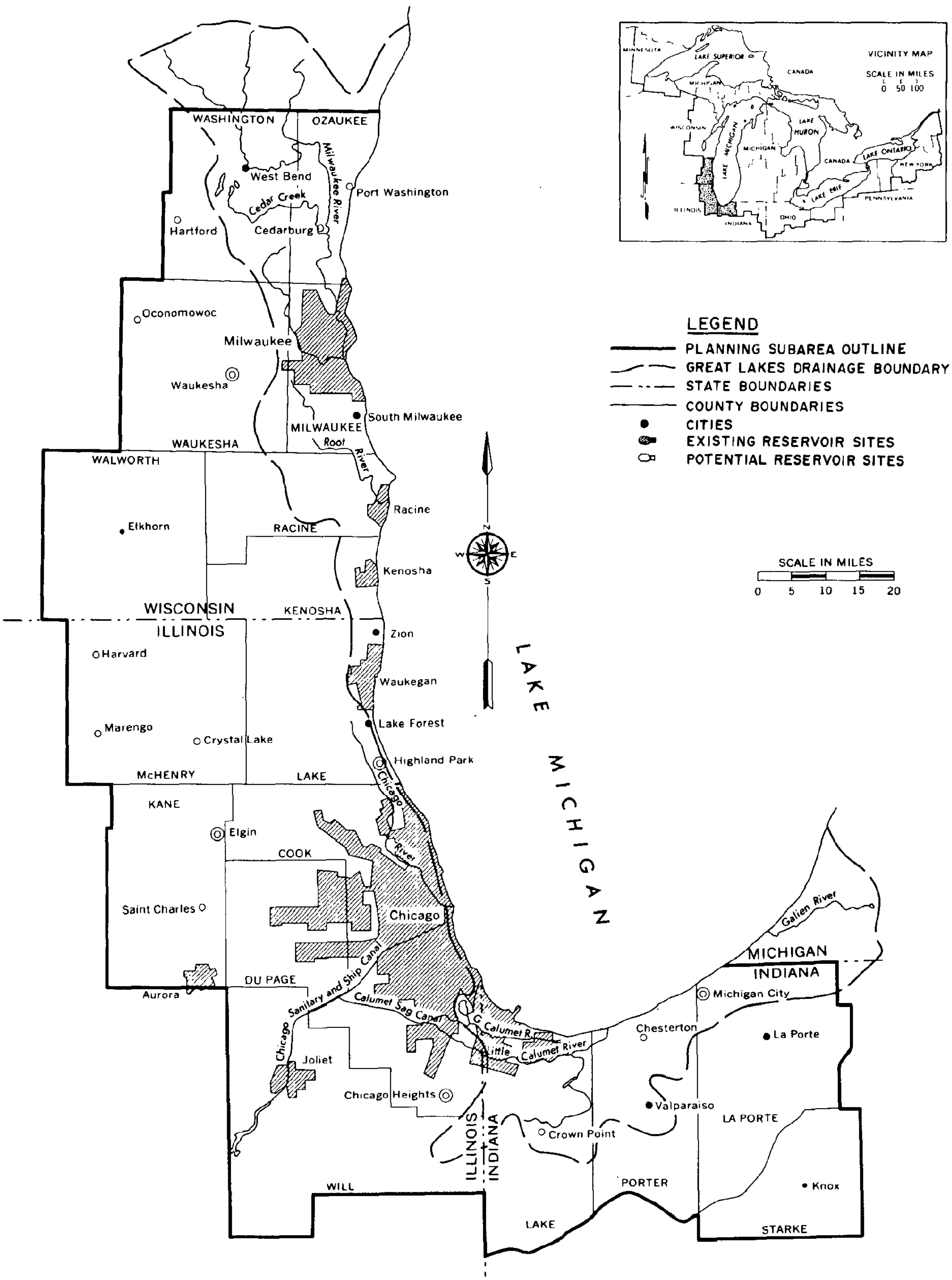


FIGURE 2-83 Reservoir Site Map, Planning Subarea 2.2

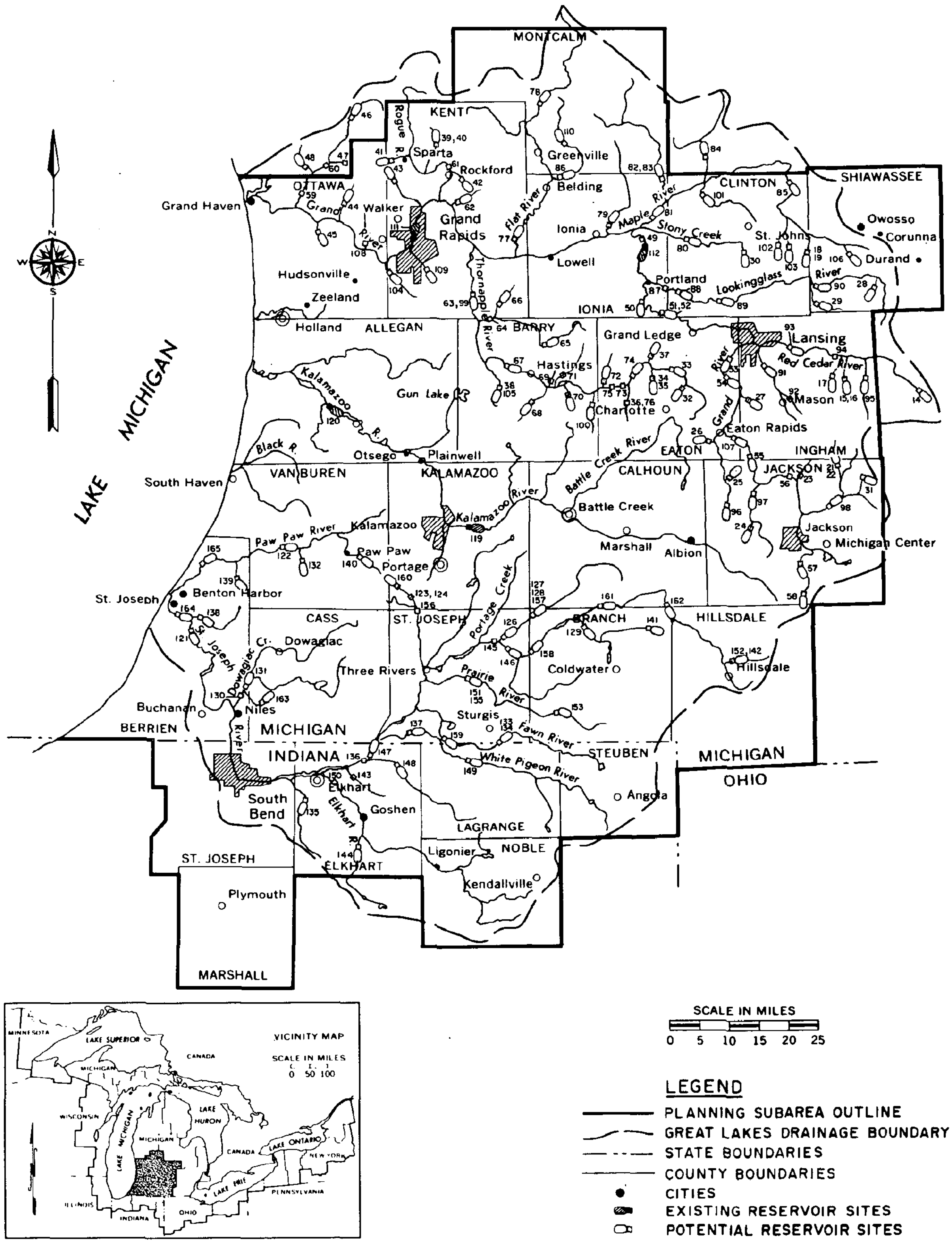


FIGURE 2–84 Reservoir Site Map, Planning Subarea 2.3

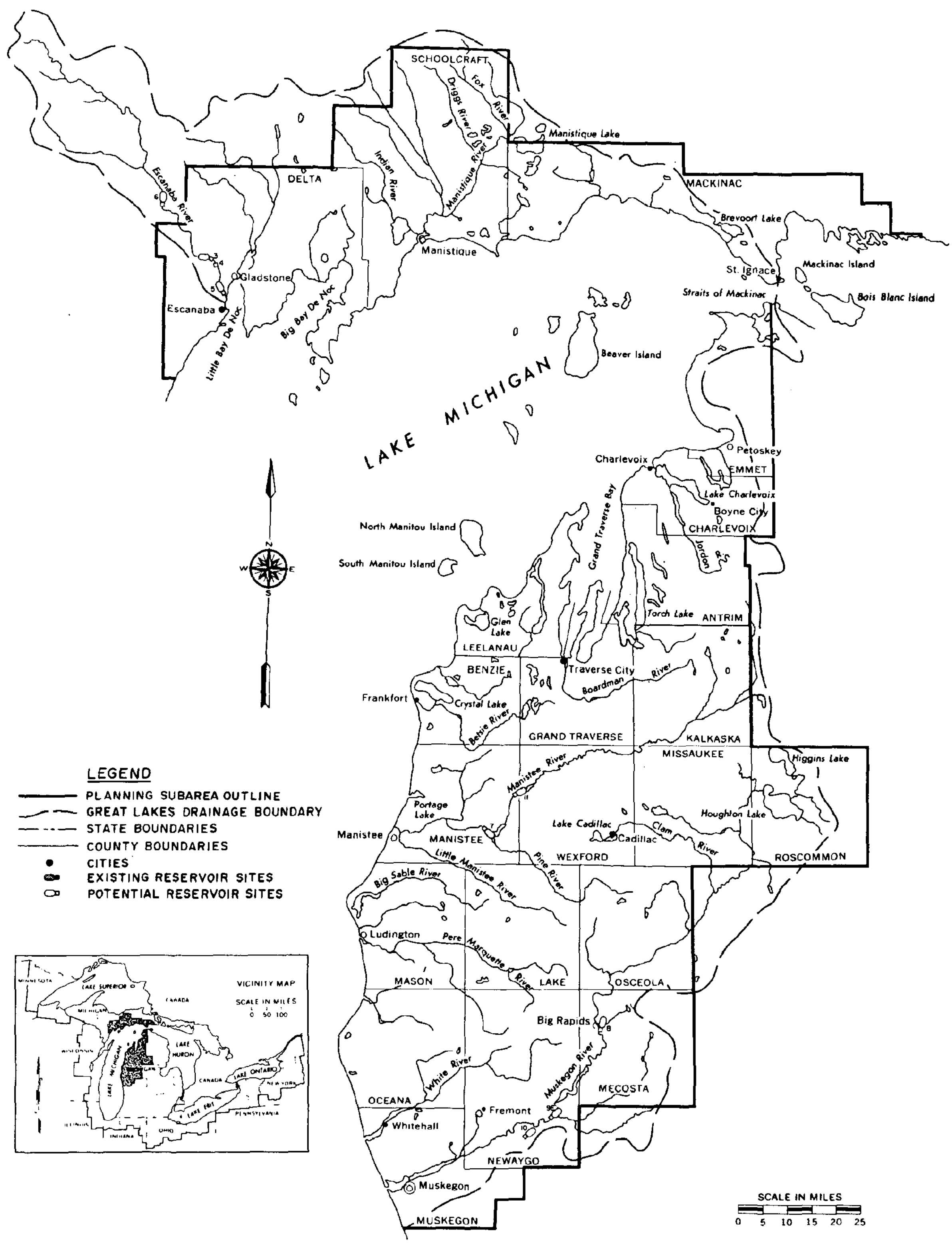


FIGURE 2-85 Reservoir Site Map, Planning Subarea 2.4

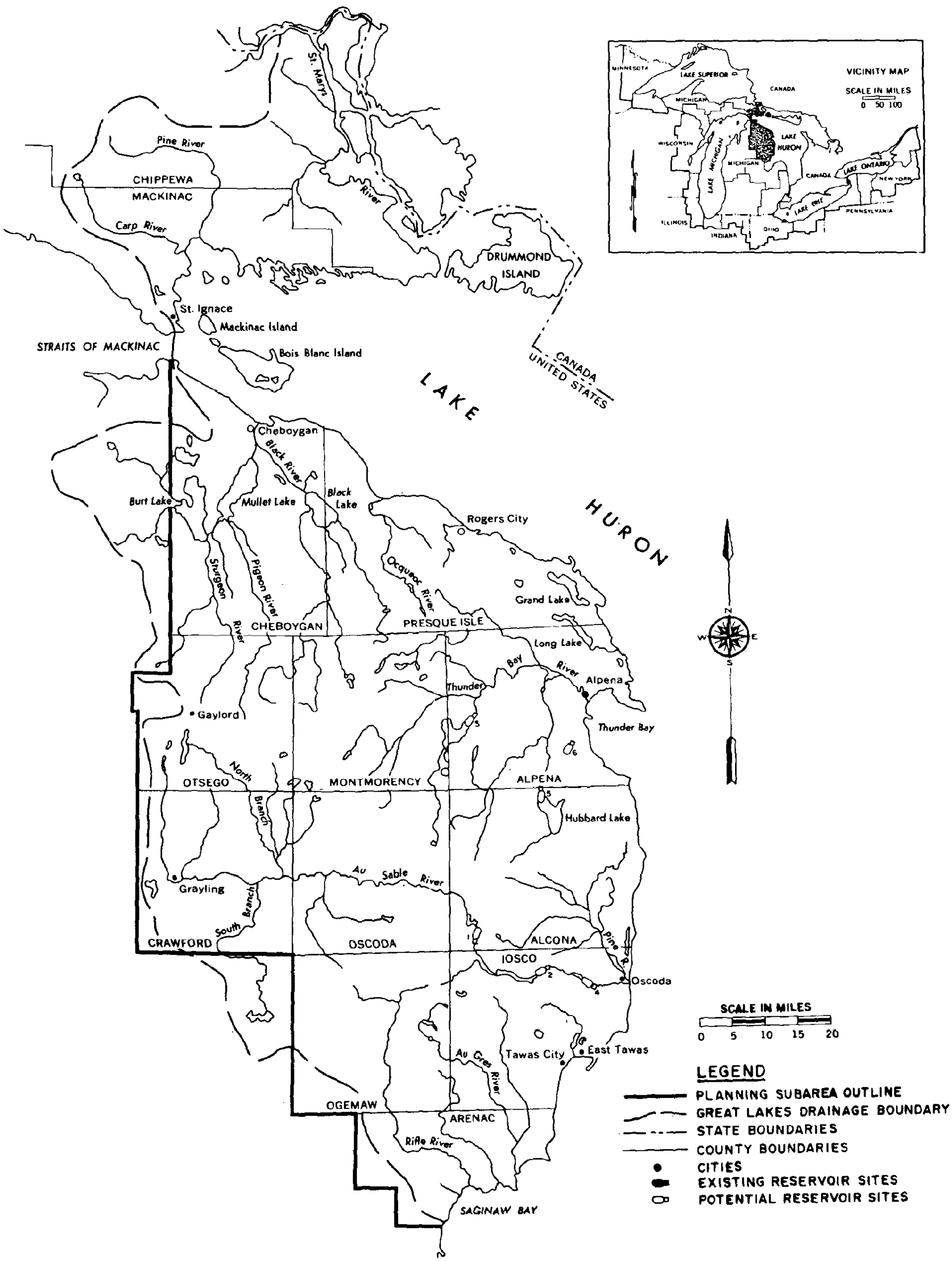


FIGURE 2–86 Reservoir Site Map, Planning Subarea 3.1

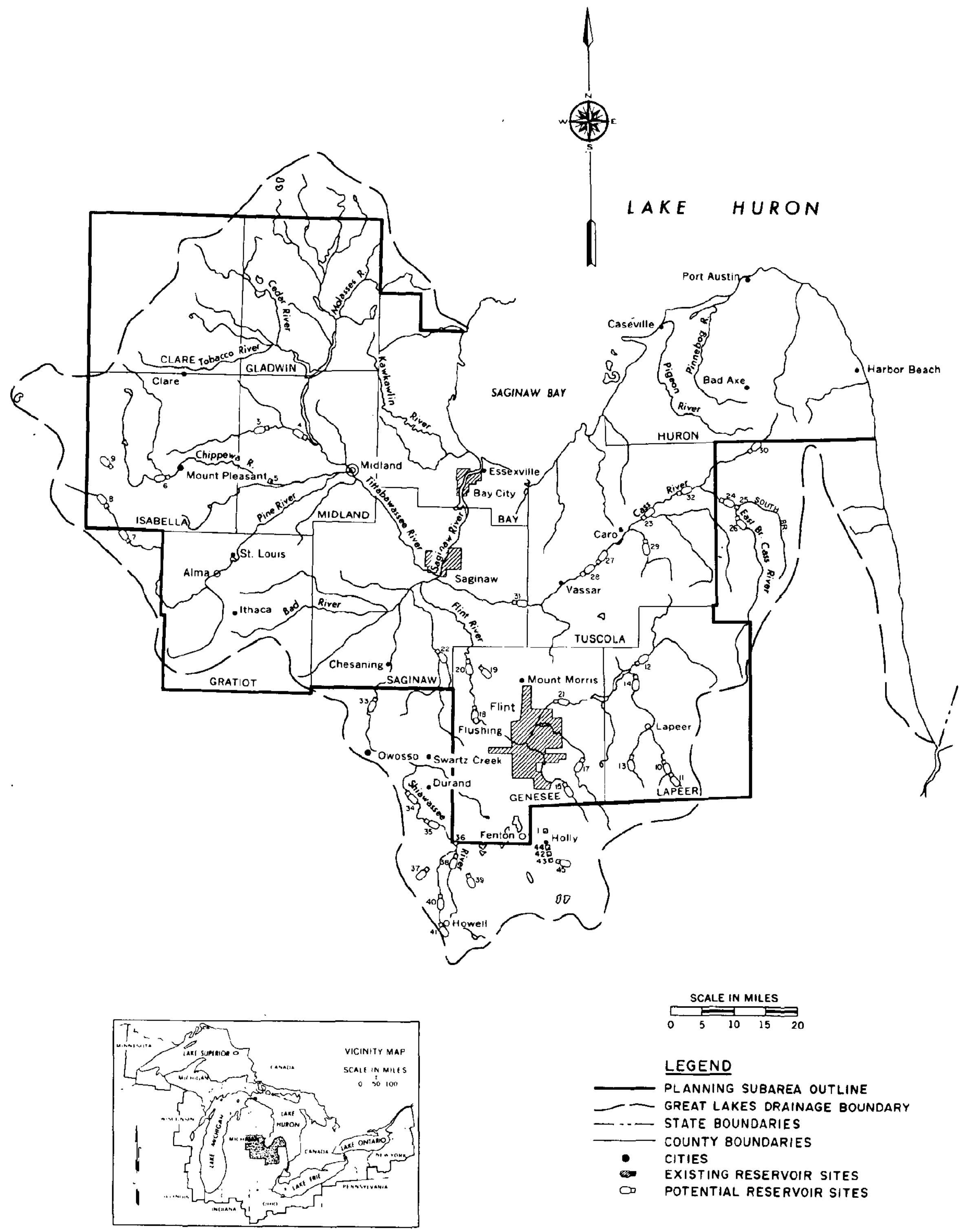


FIGURE 2-87 Reservoir Site Map, Planning Subarea 3.2

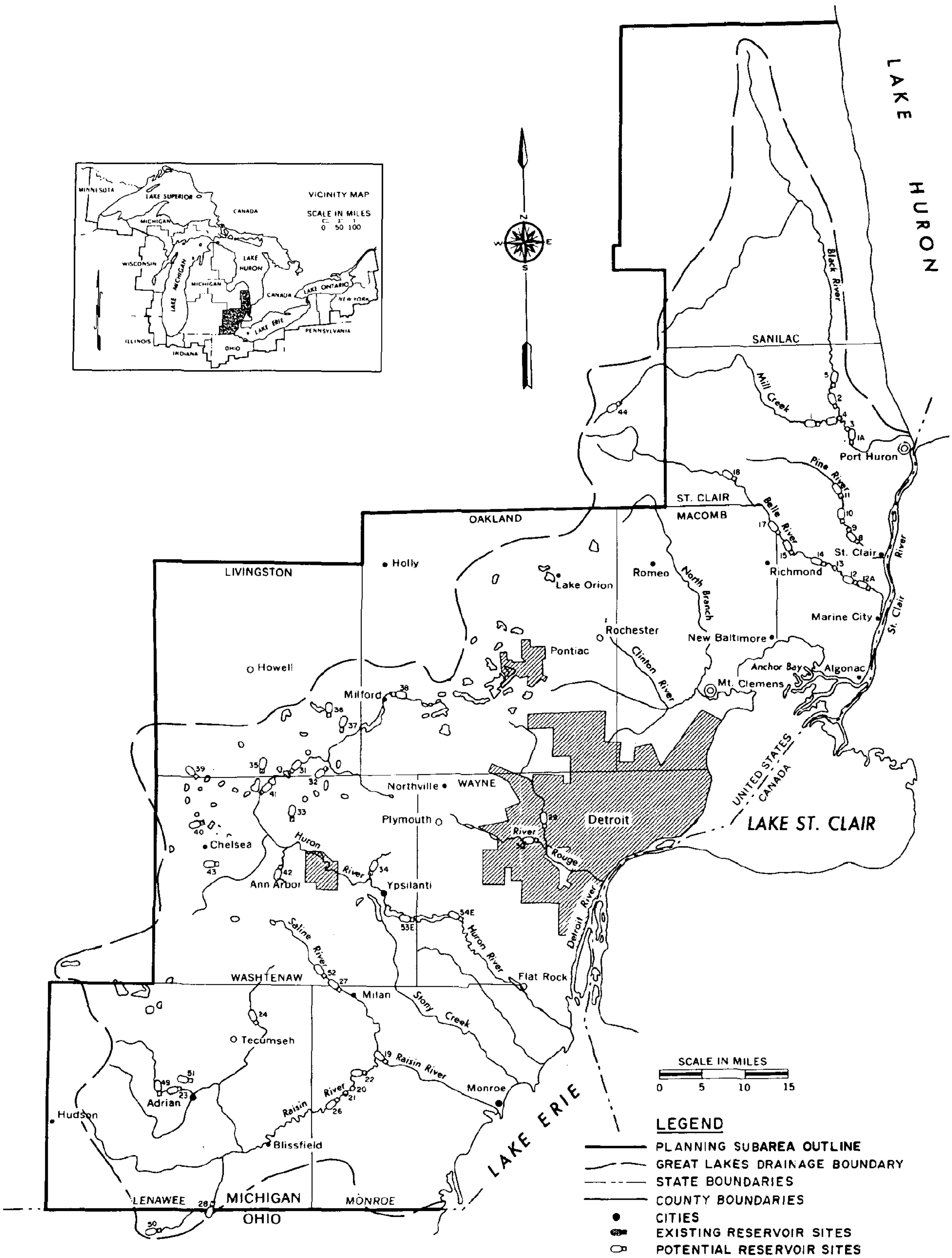


FIGURE 2–88 Reservoir Site Map, Planning Subarea 4.1

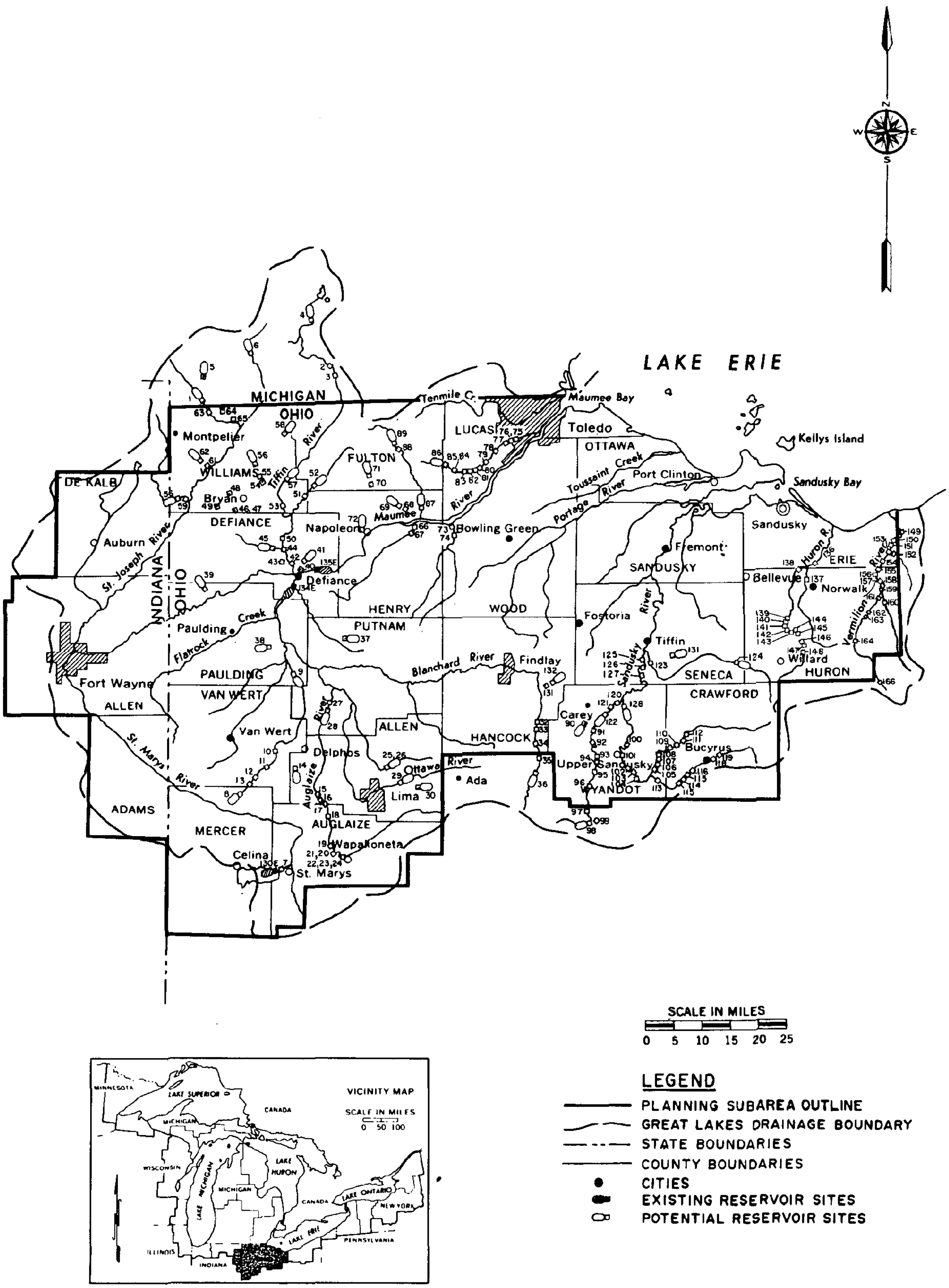


FIGURE 2–89 Reservoir Site Map, Planning Subarea 4.2

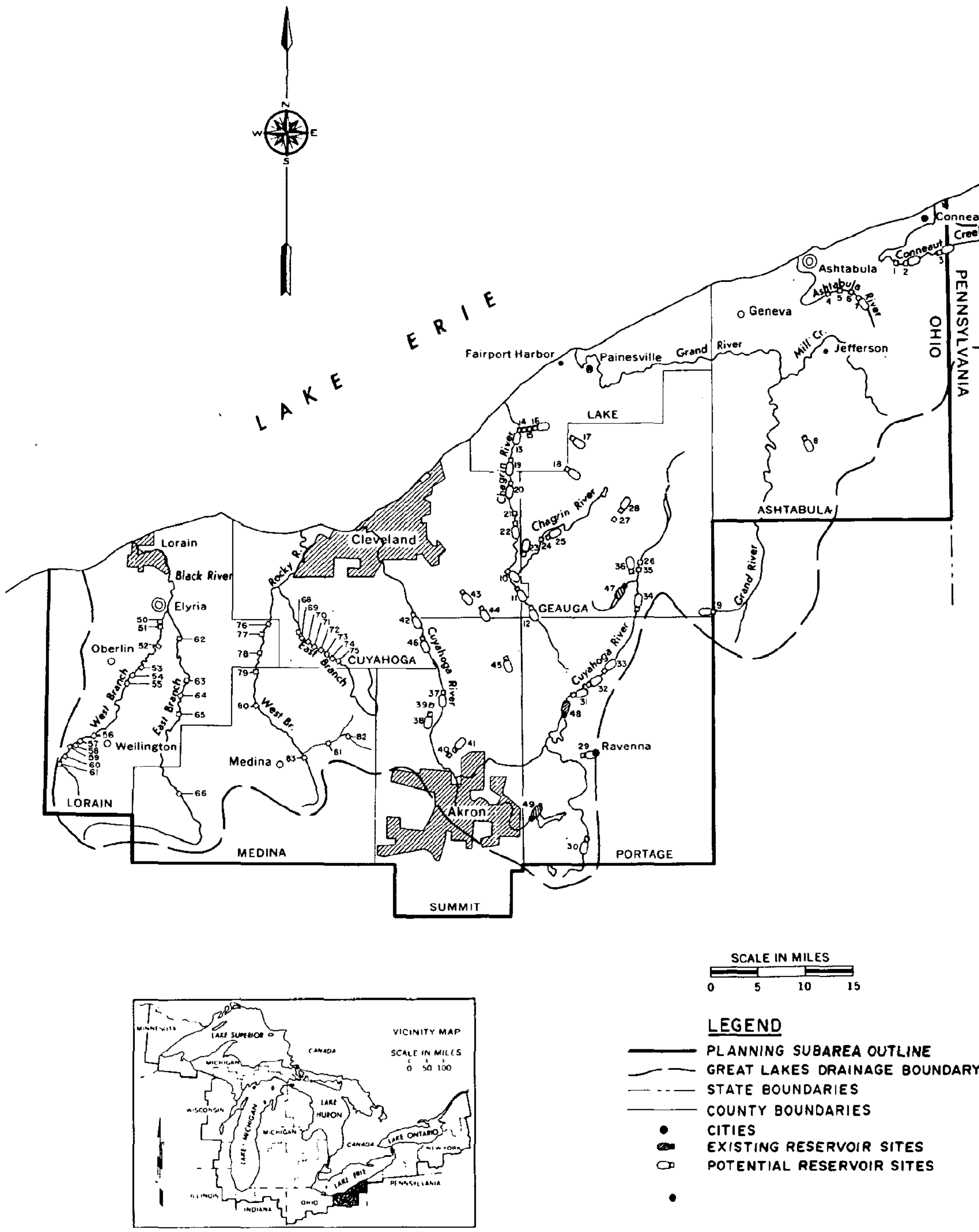


FIGURE 2–90 Reservoir Site Map, Planning Subarea 4.3

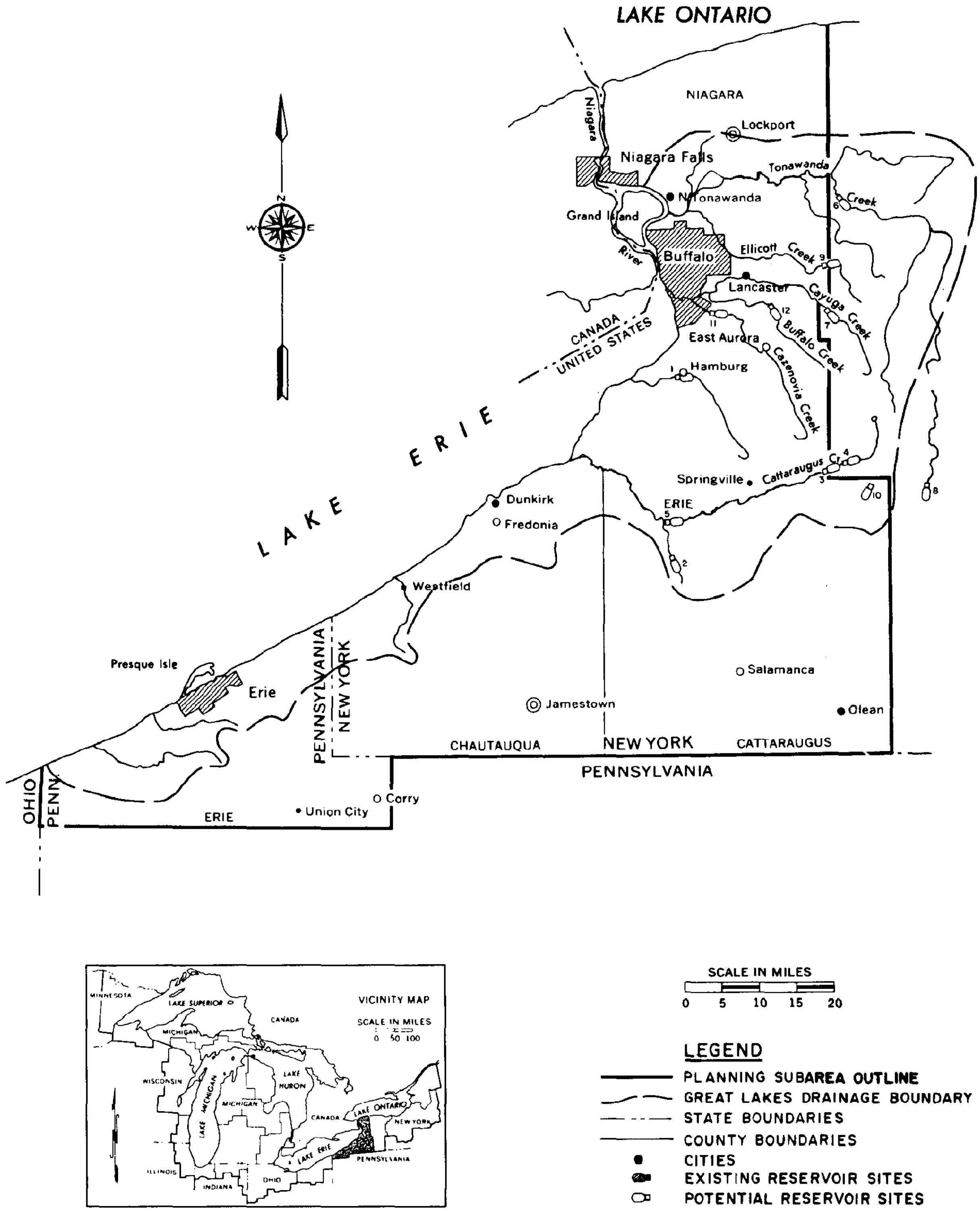


FIGURE 2–91 Reservoir Site Map, Planning Subarea 4.4

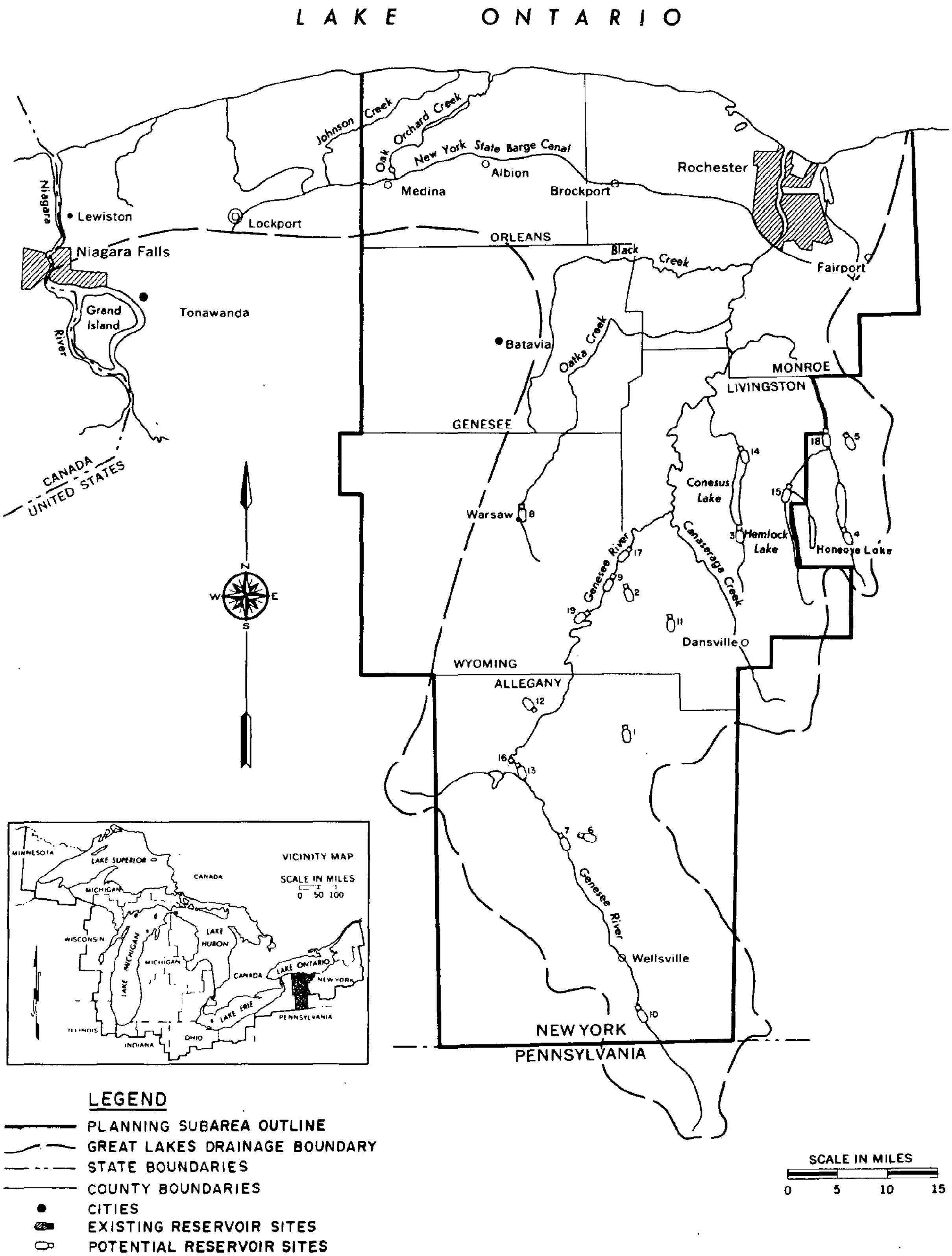


FIGURE 2-92 Reservoir Site Map, Planning Subarea 5.1

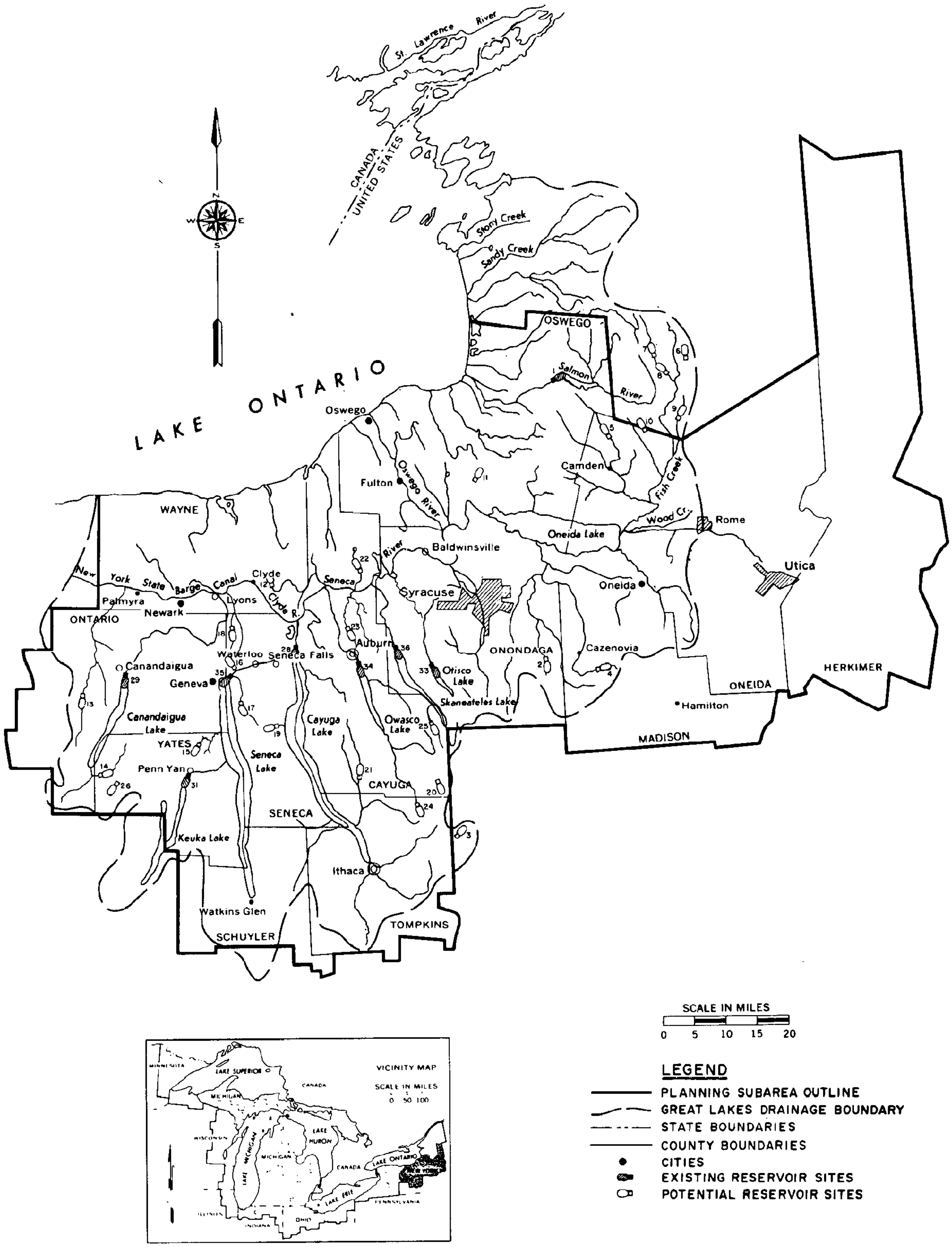


FIGURE 2–93 Reservoir Site Map, Planning Subarea 5.2

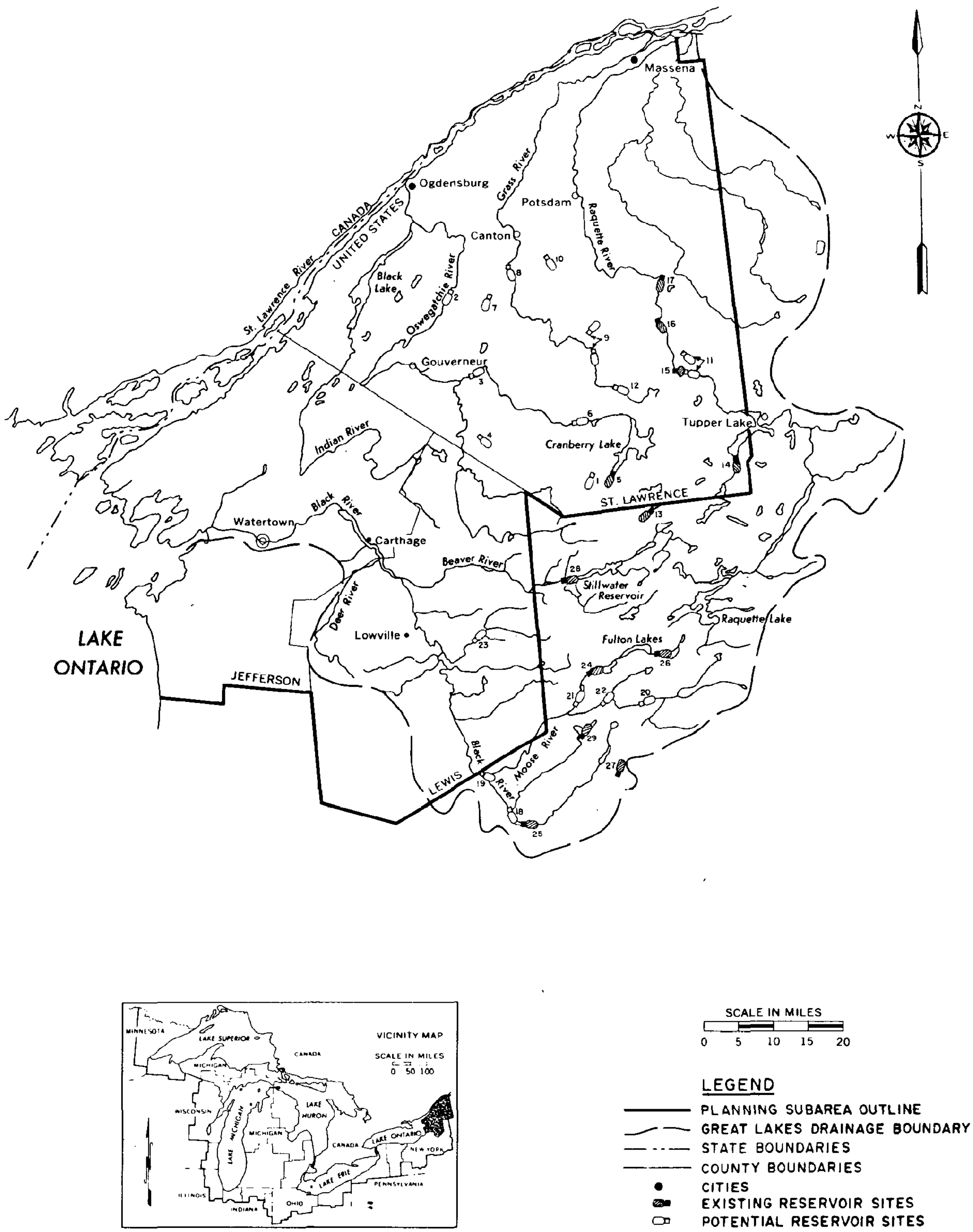


FIGURE 2–94 Reservoir Site Map, Planning Subarea 5.3

TABLE 2–6 Number of Existing and Potential Reservoir Sites with Surface Area Less Than 500 Acres

Planning Subarea	Number of Potential Sites	Number of Existing Sites
1.1	8	11
1.2	5	6
2.1	23	117
2.2	2	---
2.3	98	218
2.4	21	128
3.1	20	82
3.2	20	81
4.1	152	168
4.2	293	25
4.3	89	---
4.4	71	---
5.1	122	---
5.2	173	---
5.3	1	4

Section 7

RIVER FLOW AND FLOOD FORECASTING

7.1 General

Individual river basins vary in size, topography, soil, ground cover, and climate, and may have engineering works such as dredged channels and dams that affect the flow of water. Hydrologists design individual procedures for each river system and revise these procedures as natural and man-made alterations affect stream channels and basins.

Forecast procedures are designed by studying the past history of each stream and the relationships of storm, melting snow, soil, and river conditions to floods. Through these analyses, hydrologists develop river forecasting procedures for predicting the amount of water that will find its way into rivers and streams and the time it will take to reach them under different conditions of temperature, soil moisture, and precipitation.

River forecasting methods vary for each part of a river system. For the headwaters, early forecasts and warnings are based on radar observations and measured rainfall. To forecast for points on major tributaries, hydrologists project headwater and precipitation forecasts downstream. Stages on the main stem of the river are predicted by combining all tributary forecasts and computing the time it will take the water to reach the forecast points. Normally associated with flood-warning procedures, river forecasting can also be of value when dealing with other water management problems such as drought flows. The subjects of low-flow forecasting and the need for additional stream gaging stations to record low-flow data are discussed further in Section 8, Recommendations.

7.2 Flood Warnings

Flood warnings are forecasts of impending floods and are distributed to the public by radio and television and through local emergency forces. Careful preparation and prompt response will reduce property loss and insure personal safety.

Early flood warnings allow time for residents to leave low-lying areas and to move personal property, mobile equipment, and livestock to higher ground. Sometimes valuable crops can be harvested in advance of a destructive flood. Emergency and relief organizations can prepare to handle refugees and to combat the inevitable health hazards caused by floods.

Flood warnings can be issued hours to days in advance of the flood peak on major tributaries. Main river flood forecasts can be issued as far as several days or even weeks in advance. In general, the time lapse between rainfall or snowmelt and the rise in river height increases with the size of the river.

Before adequate procedures were developed for estimating runoff from storm rainfall, the river forecaster was forced to wait until the end of the storm and could not issue specific forecasts until some of the upstream points in the river system had crested. Runoff estimates now make it possible to prepare flood warnings as the storm progresses, so that forecasts are much more timely.

In small headwater areas subject to flash floods, the crest of a flood may occur less than an hour after the end of flood-producing rains. In such a situation, warnings are practical only when based directly on rainfall and estimates of resultant runoff. Very often in such situations, procedures must be developed which would shorten the normal time-consuming steps in the forecast procedures and produce warnings in minimal time. Radar offers possibilities in this case, calling attention to areas currently receiving heavy rain and aiding in its evaluation.

For larger drainage areas the time required to prepare forecasts is not generally as critical as for small headwater areas. This is particularly true for general rains of relatively uniform distribution in time and area. In this situation, much of the value of river forecasts lies in making possible the evacuation of property before the flood strikes.

There are cases when local inflow is an important factor. Even at points well downstream on a major river system, floods may occur within a few hours after the end of heavy rains. When the river stage has become high and nearly stationary, it is possible that a heavy rain in a portion of the drainage area immediately above a forecast point will cause a rapid rise to critical stages. In this situation, the ability to estimate runoff is required to provide the needed forecasts.

7.3 Operation of Water Control Structures

In addition to anticipating flows on uncontrolled streams, river forecasts are important for the efficient operation of any sort of water control structure or water management program.

A few water control structures are self-regulating, that is, they have fixed openings and require no manual operations. For such structures, river forecasts have the same significance as in uncontrolled streams, serving as warnings to those affected. Most water control structures, however, require varying degrees of manual control. Most levee systems have many openings which must be closed as rivers rise. If these closures are not made in time, the levee will not serve its intended purpose. Timely river forecasts are needed to give as much time as possible to make these closures. This is particularly true in cases where floods occur only rarely and crews making the closures are inexperienced. Conversely, river forecasts may indicate the river will stop rising before reaching stages requiring closure, and much work can be avoided.

Efficient operation of a dam with moveable gates is highly dependent upon accurate forecasts of inflow into the reservoir behind the dam. It is also necessary to have forecasts of river conditions downstream in order to minimize the effect of releases from the dam on critical points. This is particularly true for multipurpose dams intended for many uses such as flood control, generation of power, irrigation, navigation, and pollution abatement. Flood control is most effective when the reservoir is kept nearly empty, while most other uses are best served by holding as much water as possible behind the dam. Such conflicting interests create operational problems which can be handled effectively only with forecast information.

7.4 National Weather Service Great Lakes River and Flood Forecast Program

The National Weather Service of the National Oceanic and Atmospheric Administration provides river and flood forecasts for selected portions of the Great Lakes drainage. This service is confined to flood crest forecasts for these areas. Several river basins with flood hazards are not currently served by flood forecast programs. Table 2–7 summarizes river forecast points and hydrologic reporting stations.

The existing river and flood forecast services are supported by Weather Surveillance Radars (WSR–57) located at Weather Service offices in Minneapolis, Chicago, Detroit, Pittsburgh, and Buffalo. These facilities are operated on a continuous basis and have the capability for detection and evaluation of precipitation within a maximum radius of 125 nautical miles. The continuous radar observations are an effective source of information for the issuance of flash flood warnings. Radar also photographically records precipitation patterns at least every 15 minutes and more frequently during special situations. This provides recorded data over areas where rain gage installations are impractical or nonexistent. In addition to the WSR–57 facilities, Weather Service local use radars supplement the basic network at Cleveland, Ohio; Flint, Michigan; Fort Wayne, Indiana; and Muskegon, Michigan. Observational data are also available from Air Force radars near Oscoda, Michigan; Duluth, Minnesota; and Marquette, Michigan.

The National Weather Service provides an automated Great Lakes Wind Forecast, an automated Great Lakes Storm Surge Forecast, and continuous weather broadcasts from selected sites. The wind forecasts are from a numerical model used to forecast surface winds on Lakes Erie and Ontario out to 17 hours. This forecast is used by boating interests and for the storm surge forecasts. The automated Great Lakes Storm Surge Forecast is a computer product that forecasts the deviation from normal of the lake levels. This deviation, predicted for Buffalo, New York and Toledo, Ohio, extends out to 36 hours. The forecast is useful to shipping and power companies because abnormally high water causes flooding, while abnormally low water affects harbor operations and hydroelectric generation.

At certain locations, weather information and warnings are continuously broadcast 24 hours a day. These VHF radio weather transmissions repeat taped messages every 5 to 7 minutes. Tapes are revised and updated periodically, usually every 3 to 6 hours. Messages include weather and radar summaries, wind observations, visibility, lake conditions, and detailed local and area forecasts. The transmissions are broadcast on FM frequencies of 162.55 or 162.40 MHz. On the Great Lakes this service is provided from Sandusky, Ohio (KHB–97), Cleveland, Ohio (KHB–59), and Chicago, Ill. (KWO–39).

7.5 National Weather Service Precipitation Probability Forecast Program

One of the most important facets of any river forecasting program is the prediction of future precipitation events. The best method available today is provided by the National Weather Service's precipitation probability forecast. The probability forecast is intended to elaborate the basic weather prediction, giving the user the benefit of the weatherman's knowledge of the degree of uncertainty in the situation. In effect, the forecast translates the difference between a remote chance and a virtually sure thing into numerical terms. As applied to precipitation forecasting, probability is the percentage chance that at least one one-hundredth inch of precipitation (rain or the liquid equivalent of snow or other frozen precipitation) will fall at any selected point in the area and time period covered by the forecast.

Applied to making weather-related decisions, a 70-percent probability indicates a 7-in-10 chance of precipitation, and a 3-in-10 chance of no precipitation, at any location in the forecast area. A 30-percent probability suggests only a 3-in-10 chance of precipitation. In general, the forecasts cover 12-hour periods (sometimes refined after the first 6 hours) and moderate-sized metropolitan areas. Usually no differentiation is made for points within the forecast area.

The chance of a shower occurring in the area covered by the forecast is the product of two quantities: the probability that a precipitation-producing storm will develop or move into the area, and the percent of the area which the storm is expected to cover. Thus, in the summer, when storms tend to be more isolated or scattered in nature, the probability that an immediate area will get rain tends to be smaller than in winter.

Probabilities may be low any time of the year because the entire area covered by the forecast is not expected to be affected. For example, a forecaster can have a high degree of confidence (say 80 percent) that a storm will move through the area, but that not all of the area will be affected. Although he cannot predict exactly where precipitation will occur, he can read the weather patterns well enough to say that perhaps 40 percent of the area will be affected. Here the product of storm probability (80 percent) and expected coverage (40 percent) is 32 percent, and the forecast will call for a 30-percent chance of precipitation. Precipitation is nearly certain, but the chance it will affect you, wherever you are in the forecast area, is only 3-in-10. Table 2–8 summarizes the range of National Weather Service probability forecasts with qualifying limits.

TABLE 2-7 River Forecast Points and Hydrologic Reporting Stations

River Basin or Area	Planning Subarea	River District Office Location	Reporting Stations	Forecast Points
Grand above Grand Ledge	2.3	Lansing, Mich.	9	6
Saginaw	3.2	Lansing, Mich.	18	9
Grand below Grand Ledge	2.3	Grand Rapids, Mich.	5	5
Maumee	4.2	Fort Wayne, Ind.	28	6
Vermilion	4.2	Akron, Ohio	3	1
Cuyahoga	4.3	Akron, Ohio	3	2
Chagrin	4.3	Akron, Ohio	3	1
Genesee	5.1	Rochester, N.Y.	18	9

TABLE 2-8 Precipitation Probability Forecast Summary

Forecast Precipitation Probability (percent)	Forecaster's Range of Probabilities (percent)	Qualifying Forecast	Meaning[a]
Near zero	Less than 2	Usually no mention of precipitation	1 or less
2	2-5		
5	5-8		
10	8-15		
20	15-25	Slight or small chance	2
30	25-35	Chance	3
40	35-45		4
50	45-55		5
60	55-65	Likely	6
70	65-75		7
80	75-85	No qualifying forecast term; precipitation virtually assured.	8
90	85-95		9
Near 100	95 or more		

[a]Meaning: Cases out of 10 in which at least 0.01 inch of precipitation will occur at any point in the forecast area within the forecast period.

Section 8

RECOMMENDATIONS

8.1 General

The goals of the surface water hydrology appendix are threefold: first, to provide a good bibliography of surface water in the Great Lakes Basin; second, to provide generalized data and curves for use in preliminary planning studies; and third, to point out any shortcomings uncovered during preparation of the appendix, and thereby recommend future studies that will provide more reliable data. The following recommendations concern both data collection and data analysis.

8.2 Data Collection

The U.S. Geological Survey has completed a State-by-State analysis of the present surface water data collection network. Evaluation of available streamflow data was made to provide guidelines for planning future water resource programs. Basic steps in the evaluation procedure were: definition of the long-term goals of the streamflow data program in quantitative form; examination and analysis of all available data to determine which goals have already been met; consideration of alternate programs and techniques to meet the remaining objectives; and preparation of a proposed program of data collection and analysis to meet the remaining objectives.

Streamflow gages were grouped into four categories: natural flow, minor streams; natural flow, principal streams; regulated flow, minor streams; and regulated flow, principal streams. The dividing line between a minor and principal stream varies somewhat from State to State, but a stream with a contributing drainage area less than 500 square miles is usually considered minor. Anything larger would be termed a principal stream.

Accuracy goals and a discussion of gages to be included or excluded from each network are presented in U.S. Geological Survey Open File Reports for each State. Additional gages have been recommended for both minor and principal natural stream networks. The following is a list of those gages needed to complete the present natural flow, principal streams networks.

(1) Minnesota
  - (a) St. Louis River below Embarrass River
  - (b) Whiteface River below Meadowlands
  - (c) St. Louis River below Flood River

(2) Wisconsin
  - (a) Fox River near Montello
  - (b) Manitowoc River near Manitowoc

(3) Michigan
  - (a) Munuscong River near Kelden
  - (b) Pine River near Rudyard
  - (c) Whitefish River near Rapid River
  - (d) Escanaba River near Arnold
  - (e) St. Joseph River near Mendon
  - (f) Manistee River near Sharon

Needs for surface water data on the natural flow, principal streams networks of other States in the Great Lakes Basin have been met or are being filled by gages currently in operation. There appears to be some need for gages on natural flow, minor stream networks. For example, 17 additional gages have been recommended for minor streams in the State of New York.

In addition, the Environmental Protection Agency has identified 14 sites where streamflow data are not being collected, but are required for correlation with quality-of-water data. These sites are shown in Table 2–9.

This program will generally fulfill the needs of runoff determination throughout the Great Lakes Basin. However, additional gaging programs may be necessary to satisfy more specific needs that can be satisfied with gaging programs of shorter duration, perhaps 3 to 5 years. An example concerns the runoff from small watersheds. Recognizing the expertise of the Soil Conservation Service in the analysis of runoff from small watersheds, it is recommended that, under their leadership, additional studies be made to determine the need and location for surface water gaging stations on watersheds of less than 250,000 acres in the Great Lakes Basin.

8.3 Data Analysis

Many of the curves and much of the data presented in this appendix are generalized and should be used for preliminary planning purposes only. Detailed analyses required to provide highly reliable data for all parts of the Great Lakes Basin are beyond the scope of this appendix and in some cases are presently unattainable. However, the following recommendations are made for improving the basic data and methods included here in the event more precise studies are required.

(1) frequency analysis of peak flows—projecting the magnitude of rare flood peaks, based on given periods of record, is one of the most important facets of surface water hydrology. However, no method has been developed to date that is completely satisfactory when analyzing the rare occurrence. Continuing research efforts are needed in this area. In the meantime, studies should be undertaken to develop regional parameters for each hydrologic area in order to estimate peak runoff from ungaged streams. The factors which should be considered in detail when developing hydrologic frequency data for a specific problem area are regional skew coefficients, regional volume-frequency information, and impact of existing reservoirs.

(2) frequency analysis, low flows—low-flow periods have been studied for some time in regard to water availability studies. However, the subject of low-flow analysis has recently received more attention because of increased public awareness of water resource problems. To better assess the problems brought on by droughts and other low-flow periods, more information is needed. Hydrologic factors that must be considered when analyzing specific low-flow problem areas are regional low-flow curves through correlation, seasonal variations (climatic conditions), and forecast of droughts and low-flow periods.

(3) flow duration—further consideration should be given to development of generalized flow duration data for each hydrologic area from the specific site information developed by the U.S. Geological Survey.

(4) storage yield—the primary recommendation concerning storage yield studies would be to analyze existing data in the Great Lakes Basin using one of the statistical methods now available. Other recommendations include development of a more refined accounting of evaporation losses and development of regionalized curves or data for each hydrologic area.

(5) routing studies—the need to better describe the movement of streamflow through a river system is becoming more acute as water-related studies are expanded to encompass entire basins, with each basin having many potential sites for multipurpose storage. Because of the integrated operation required within a system of reservoirs, routing characteristics for both high and low flows must be more precisely defined using existing techniques or by developing new techniques.

8.4 Additional Hydrologic Research and Development Required

Based on the unique hydrologic aspects of the Great Lakes Basin, additional research and development are recommended for application to the following factors:

(1) peak flows—evaluate more precisely the effects of topography and land management on peak flows

(2) low flows—determine:

(a) the most representative hydrologic areas to be used in generalized low-flow analyses

(b) the effect of ground water and streamflow components by percent

(c) the most applicable method of frequency analysis (analytical or graphical, skew coefficients, or zero flow occurrences)

(d) the quantitative infiltration rates for each hydrologic area

(e) drought indexes

(3) snowmelt runoff—using results of snowmelt research for mountainous regions, determine if and how they can be adapted to the Great Lakes Basin. In addition, initiate research to investigate the peculiarities of the Great Lakes Basin as they might affect snowmelt runoff.

(4) stream forecasting—future requirements of the National Weather Service River and Flood Forecast program

(a) expansion of the river and flood forecast program to provide service to the remaining areas with flood hazards

(b) development of continuous flow forecasts for selected rivers for water quality and quantity management

(c) Great Lakes inflow-outflow forecasts, both monthly and annually, to aid in operational decisions and management of the hydrologic resources of the Basin

(d) expansion of the river and rainfall

data network to more clearly define and document the water resources of the Basin and to provide more definitive data for future studies

(e) expansion of the storm surge program

(f) expansion of the VHF continuous weather broadcast program

TABLE 2-9 Required Streamflow Data Collection Sites

Stream	Latitude	Longitude	OWDC Number[a]
St. Louis River, Minn.	47°21'	92°36'	48078
Grand Calumet River at Nohman Avenue, Chicago, Ill.	41°30'	87°30'	48077
Wolf Lake at Chicago, Ill.	41°39'	87°32'	48070
Huron River at the mouth, Ohio	42°05'	83°11'	48076
Portage River at railroad bridge at Woodville, Ohio	41°26'58"	83°21'29"	48071
Grand River at Painsville, Ohio	41°44'09"	83°15'59"	48073
Ashtabula River at Ashtabula, Ohio	41°54'00"	80°47'44"	48072
West Twin River near Two Rivers, Wis.			
Tonawanda Creek near Millersport, N.Y.	43°04'	78°40'	48075
Pentwater River near Pentwater, Mich.			
Irondequoit Creek at Penfield, N.Y.	43°07'	77°35'	48074
Pettibone Creek at Great Lakes Training Center, Ill.			
Big Cedar River near Cedar River, Mich.[b]			
Whitefish River near Rapid River, Mich.[b]			

[a]Office of Water Data Collection, U.S. Department of the Interior.

[b]Includes in previous list.

SUMMARY

Objectives

The overall objective of this appendix is to provide a generalized evaluation of surface water runoff entering the five Great Lakes from tributary streams in the United States. Of the 298,000 square miles in the entire Great Lakes Basin, approximately 115,000 square miles constitute the tributary area within the United States and 88,000 square miles lie within the borders of Canada. An analysis of runoff potentials from tributary streams in Canada has not been made a part of this appendix. The appendix has been developed only to the detail and scope required to determine basic information for a comprehensive framework plan for management of water and related land resources of the Great Lake Basin. Hydrologic determinations formulated in this appendix were based on current information already available for the Great Lakes Basin. No new basic data were gathered for the appendix. Data concerning surface water generated in the Canadian portion of the Great Lakes Basin are available in publications by the Inland Waters Branch, Department of Energy, Mines and Resources—Surface Water Data, Ontario.

Data Collection

Within the United States portions of the Great Lakes Basin the U.S. Geological Survey is the prime agency responsible for gathering, recording, and publishing of data on surface water hydrology. The most complete source of published data is the Water Supply Papers of the U.S. Geological Survey. The data are collected and prepared for publication in cooperation with other Federal, State, local, and private agencies. To a more limited extent and for specific purposes, many other Federal, State, county, and municipal agencies plus public and private corporations and individuals gather and record surface water data not published in the Water Supply Papers.

Data Analysis

Analyses of surface water data are grouped into five sections for presentation in this appendix: Runoff Analysis, Flood Characteristics, Drought Flows, Surface Water Availability, and Reservoir Sites. The contents of each section are discussed briefly in the following paragraphs.

Runoff Analysis

Average monthly runoff has been tabulated for 143 stations in the Great Lakes Basin. In addition, a graph for one key station in each planning subarea has been made, showing with the average monthly runoff, the maximum and minimum runoff experienced for each month during the period of record.

Flood Characteristics

Statistical information has been tabulated from the annual peak discharge-frequency curves of 187 stations. This information consists of peak flow and maximum stage recorded at each station along with the 2-year, 50-year, and 100-year frequency discharges expected to occur at each station. A generalized peak frequency curve has been provided for each planning subarea. This curve, by itself or in conjunction with one of the previously described curves, will enable a frequency curve to be estimated for any site within the Great Lakes Basin. Flood volume-frequency curves were not computed as they are beyond the scope of this report.

Drought Flows

Low-flow statistical data are presented for 154 stations. Data consist of the lowest instantaneous, 1-day average and 7-day average flows ever recorded at each of those stations. A probability analysis was made to determine the 1-day, 30-year, and 7-day, 10-year low flows that might be expected to occur at each station.

Surface Water Availability

Cumulative mass curves have been drawn for one key station in each of the 15 planning subareas and analyzed to develop generalized storage-yield relationships. The latter curves enable an estimate to be made of the storage required to sustain a prescribed flow at a site within a given planning subarea. Flow storage statistical probability techniques are available but were beyond the scope of this report.

Reservoir Sites

An attempt was made in this report to identify all existing and potential reservoir sites within the Great Lakes Basin. More than 2,500 sites were found and analyzed to determine capacity and surface area. However, because the smaller, low capacity sites would not have significant impact on framework-scope study results, only 672 sites with more than 500 acres of available surface area were included in this section. Information on all sites is included in working papers on file in the Great Lakes Basin Commission office.

GLOSSARY

acre-foot—a unit for measuring the volume of water. It is equal to the quantity of water required to cover one acre to a depth of one foot and is equal to 43,560 cubic feet or 325,851 gallons. The term is commonly used in measuring volumes of water used or stored.

annual flood—the highest peak discharge in a water year.

average discharge—the arithmetic average of all complete water-years of record whether or not they are consecutive.

consumptive use—the quantity of water discharged to the atmosphere or incorporated in the products of the process in connection with vegetative growth, food processing, or an industrial process.

cubic feet per second (cfs)—a unit expressing rates of discharge. One cubic foot per second is equal to the discharge of a stream of a rectangular cross section, 1 foot wide and 1 foot deep, flowing water an average velocity of 1 foot per second.

cubic feet per second per day (cfs day)—the volume of water represented by a flow of one cubic foot per second for 24 hours. It equals 86,400 cubic feet, 1.983471 acre-feet, or 646,317 gallons.

datum level—the zero with reference to which the altitudes of land surfaces and the depths of the sea are determined.

drainage area—the drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.

exceedence frequency—percentage of values that exceed a specified magnitude.

flood routing—the process of determining progressively the timing and shape of a flood wave at successive points along a river.

flow duration curve—a cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded.

framework study (Great Lakes)—a broad-gauged study for the development of the water and related land resources of the Great Lakes Basin to make the best use of such resources to meet the Basin's needs and make the greatest long-term contribution to the economic growth and social well-being of the people of the Basin and the nation.

hydrologic area—an area delineated on the basis of a consistent relationship between drainage areas and mean annual floods among streams in that area.

hydrologic gaging station—a particular site on a stream, canal, lake, or reservoir where systematic observations of gage height or discharge are obtained.

hydrologic gaging station number—assigned location identifier employed by United States Geological Survey.

hydrostatic pressure—pressure exerted by or existing within a liquid at rest with respect to adjacent bodies.

infiltration—movement of water through the soil surface and into the soil.

interception—rainwater retained by leaves and stems of vegetation.

interpolate—to estimate intermediate values of a function between two known points.

interstices—the openings of pore spaces in a rock. In an aquifer, they are filled with water.

low-flow frequency curve—a graph showing the magnitude and frequency of minimum flows for a period of given length.

Pearson Type III function—family of asymmetrical, unbounded, ideal frequency distributions, of which the normal distribution is a special case.

percolation—the movement, under hydrostatic pressure, of water through the interstices of a rock or soil.

plan area (Great Lakes)—geographic areas drained by designated major tributaries or groups of tributaries of the Great Lakes Basin. The plan areas of the Great Lakes Basin are: 1.0—Lake Superior; 2.0—Lake Michigan; 3.0—Lake Huron; 4.0—Lake Erie; 5.0—Lake Ontario.

runoff—that amount of the precipitation that appears in surface streams. It is the same as streamflow unaffected by artificial diversions, storage, or other works of man in or on the stream channels.

stage—the height of the water surface above or below an established datum plane. Also a gage height.

transpiration—the process by which water vapor escapes from the living plant, principally the leaves, and enters the atmosphere.

water year—the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends.

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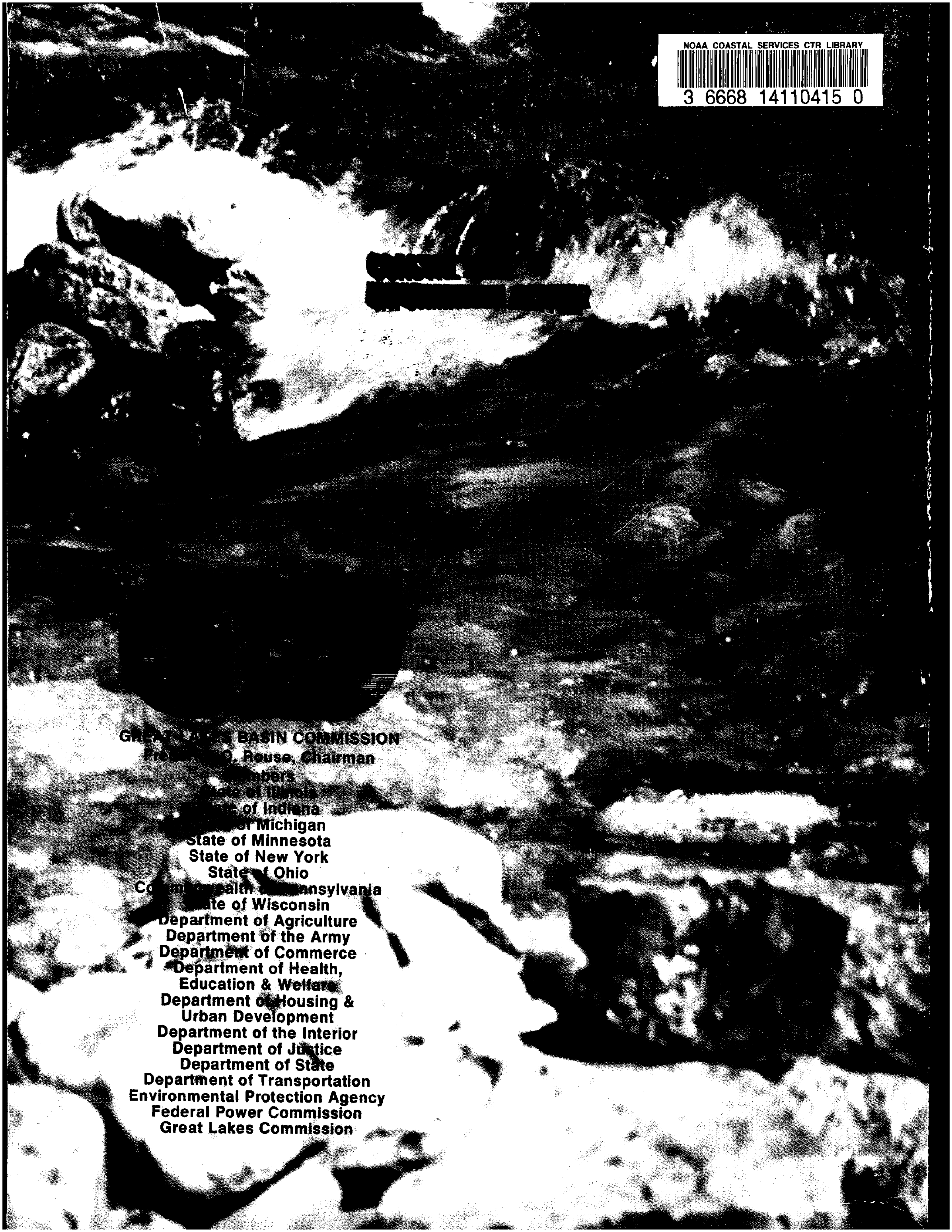

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